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SES MULTI-PURPOSE SHIP STUDY. TRANSPORT APPLICATION. VOLUME 1. --ETC(U)

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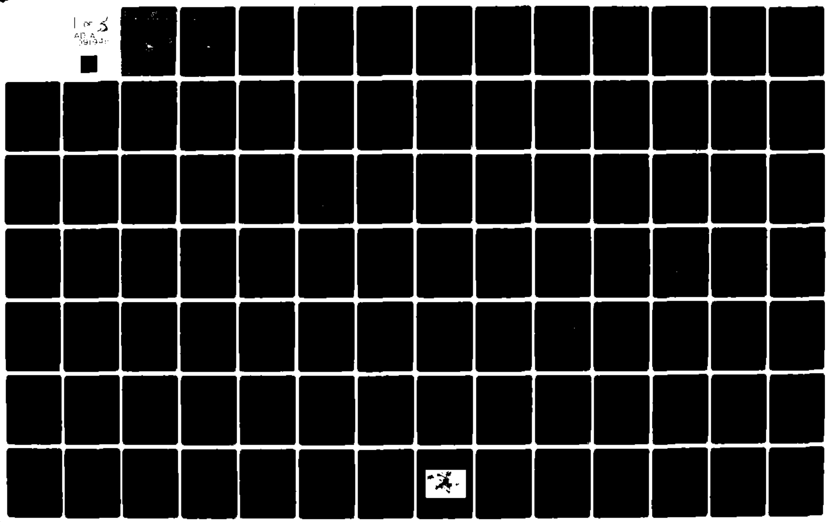

LEVEL II ②

SES MULTI-PURPOSE SHIP STUDY

(TRANSPORT APPLICATION)

TECHNICAL REPORT

SURFACE EFFECT SHIP ACQUISITION PROJECT
NAVAL SEA SYSTEMS COMMAND
WASHINGTON, D.C.

(2)

SES MULTI-PURPOSE SHIP STUDY.

(TRANSPORT APPLICATION).

Vol. 1. Technical Summary.

TECHNICAL REPORT

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SURFACE EFFECT SHIP ACQUISITION PROJECT

NAVAL SEA SYSTEMS COMMAND

WASHINGTON, D.C.

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VOLUME 1 – TECHNICAL SUMMARY

SES MPS STUDY

(TRANSPORT APPLICATION)

JULY 1980

FOREWORD

This report describes the MULTI-PURPOSE SHIP (MPS) and its application in Military Transport, and was prepared by the staff of the Navy's Surface Effect Ship Acquisition Project. The study report contains two volumes:

Volume I includes 8 sections. Section 1 presents a brief introduction; Section 2 summarizes the MPS point design characteristics; Section 3 describes the ship's performance; Section 4 compresses descriptions of all the ship's subsystems in a concise narrative form with supporting illustrations; Section 5 delineates the ship's crew and functions; Section 6 analyzes the compatibility between the stowage and handling requirements of the payload and the various options available in the selection of primary ship proportions and design features; Section 7 highlights the significant conclusion resulting from the study effort; Section 8 presents the technical appendices supporting the MPS point design.

Volume II, COST REPORT, includes seven sections plus appendices covering such topics as the overall acquisition and contracting program, period of performance, lead times required for the purchase of various material and equipments, manpower requirements, and shipbuilding facilities.

The COST REPORT also contains estimates for the lead ship, the first production ship, and a follow-on production for a total production of 14 ships.

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I. INTRODUCTION

The technical and production planning material in this report is based on 14 years of technology pursuits, test and evaluation, production analysis, manufacture of large surface effect craft, and a wealth of corporate knowledge and expertise residing in the U.S. Navy Surface Effect Ships Project Office (SESPO) and the Navy David Taylor Ship R & D Center. The concept disclosed represents a distillation of this base and a coalescence of SES attributes in an eminently practical ship concept of unprecedented performance.

This ship concept was then applied to a real world military operation, the rapid transport/deployment of weapons and materials, and tested. Application of the concept was prompted by a study by Information Spectrum, Inc., which defined general rapid deployment requirements, and a later study by Rohr Marine, Inc. entitled "SES Multi-Purpose Transport (MPT)" which established the feasibility of utilizing surface effect ships to meet future needs of high speed marine transport. This report goes several steps beyond the latter by reducing the transport ship to one that can be built and operated in accordance with common marine shipbuilding and operating practices.

Additionally, the attractive performance spectra of the MPS suggests multi-purpose applications of the hull in missions other than sealift. Several such potential uses are: amphibious assault operations; assault follow-on-echelon resupply; high value cargo/ordnance delivery to a combat task group or forces afloat; fleet air maintenance and repair of all air capable ships; the use of the MPS itself as an air capable ship; and in general, commercial applications.

2. MPS REPORT SUMMARY

The MPS design evolved largely from hydrodynamic data, performance prediction techniques, structural system, propulsion, lift fans, cushion seals, and ship control technology developed within the scope of the SES Program. As a result, all technology selected for this point design is either commercially available or has been subjected to considerable testing and/or operation within the scope of the SES Development Program or within conventional ship programs. Additionally, the concept utilizes many innovations that have helped to evolve a more mature SES technology that is both practical and applicable over a broader range of missions, as well as highly competitive with other types of transportation systems. The summary, which follows, describes in detail the first ship of its kind to integrate all of the above attributes.

2.1 DESIGN RATIONALE

For a number of years the Surface Effect Ship (SES) program has had as its centerpiece the 3000-ton SES frigate (3KSES). This ship was characterized by propulsion power approaching that of an aircraft carrier, with high technology systems and construction methods throughout. It was designed to "transit hump drag" and actually plane ahead of the ship's pressure wave at speeds approaching 100 knots. The technical, building and funding challenges were substantial.

During 1976 the Navy SES team set about studying alternate ship concepts which derived the most benefits from the ship's low hull drag characteristics, and which stressed reasonable costs and conventional ship building practices. After the termination of 3KSES in 1979, this process was accelerated. A hull form and configuration began to take shape as the following trade-offs were made:

a. Speed -- traded for range, endurance and seakeeping.

b. Lightweight structures (low ship weight fraction) -- traded for cheaper materials and easier fabrication.

c. Power -- traded for availability and ease of maintenance, support and reliability.

d. Low drag high technology seals -- traded for simplicity, low cost, ease of maintenance and reliability.

e. Lightweight developmental systems -- traded for cheaper, more durable available systems.

f. Minimum hull drag -- traded for lighter ship dynamic loading and simpler structures.

2.2 TECHNICAL AND PHYSICAL FEATURES DERIVED FROM THE DESIGN RATIONALE

a. The ship size is compatible with passage through the Panama Canal. Its overall length is 686 feet, its overall beam is 105 feet and maximum displacement is 15,000 long tons (LT).

b. The shape is that of a high length to beam ratio ($L_c/B_c = 8.5$) ship which yields the drag characteristics of that shown in Figure 2-1.

c. All propulsion, fan and electrical power is provided by production-run prime movers, viz, LM-2500 gas turbines and SACM diesels.

d. Sidehulls are large displacement (buoyant) forms with an elevated wet deck between to accommodate high sea states, off-cushion operations as a standard mode, and all machinery installations in the sidehulls for flexibility in ship arrangements.

e. The propulsion arrangement is CODOG with operational power options down to 14,000 hp (diesel) available for long range economical transits, and up to 120,000 hp (gas turbine) for high speed missions.

f. Simple bag and finger type bow seals are similar to those used in commercial applications throughout the world.

g. The ship is large with high cushion density to take full advantage of the favorable payload to power relationships (and other attributes) that exist at such sizes.

h. The ship is, in the main, shaped and constructed with high strength (HY100) steel to accommodate modern ship construction techniques.

i. Controllable pitch propellers are relatively small with large hubs installed in such a configuration as to reduce loading and ensure long term reliability.

2.3 OPERATIONAL FEATURES REALIZED

The ship can operate in either of two modes -- cushionborne or hullborne. With a light ship weight of about 5400 tons, the cushionborne range and speed characteristics vary as a function of loading (payload plus fuel) in accordance with the curves in Figure 2-2. Figure 2-3 depicts characteristics in the hullborne mode.

Fuel usage is optimized by selection of power settings which best fit the operational or transit needs of the mission. The fuel efficiency (basically, miles per gallon) of the MPS far exceeds any ship of comparable size or speed.

Comparability of the MPS to other ships is complex because there are so many variables involved. The MPS's payload to full load displacement fraction is good with a very high volumetric capability. See Table 2-1 for some comparisons of the MPS in a container ship configuration. Appendix A provides additional comparisons of the MPS with other cargo ships.

CUSHIONBORNE DRAG VS VELOCITY IN SS 3

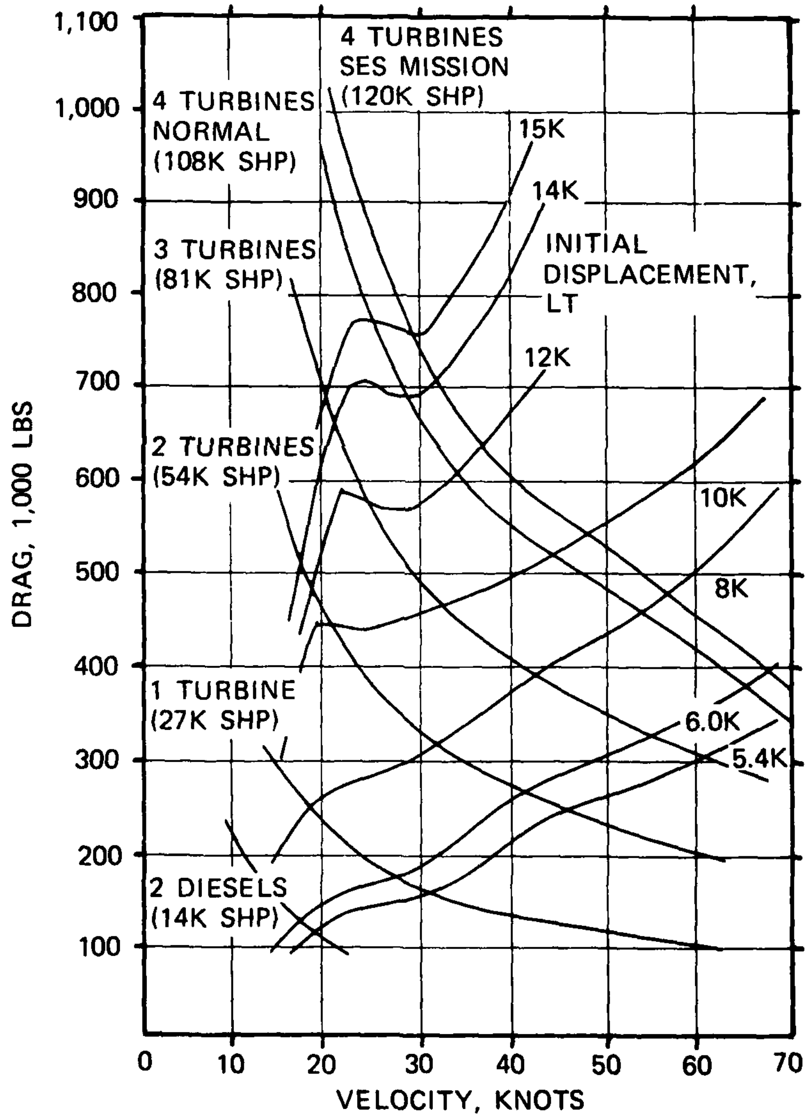


FIGURE 2–1

AVERAGE VELOCITY VS RANGE AT MISSION POWER,
CUSHIONBORNE IN SS 3

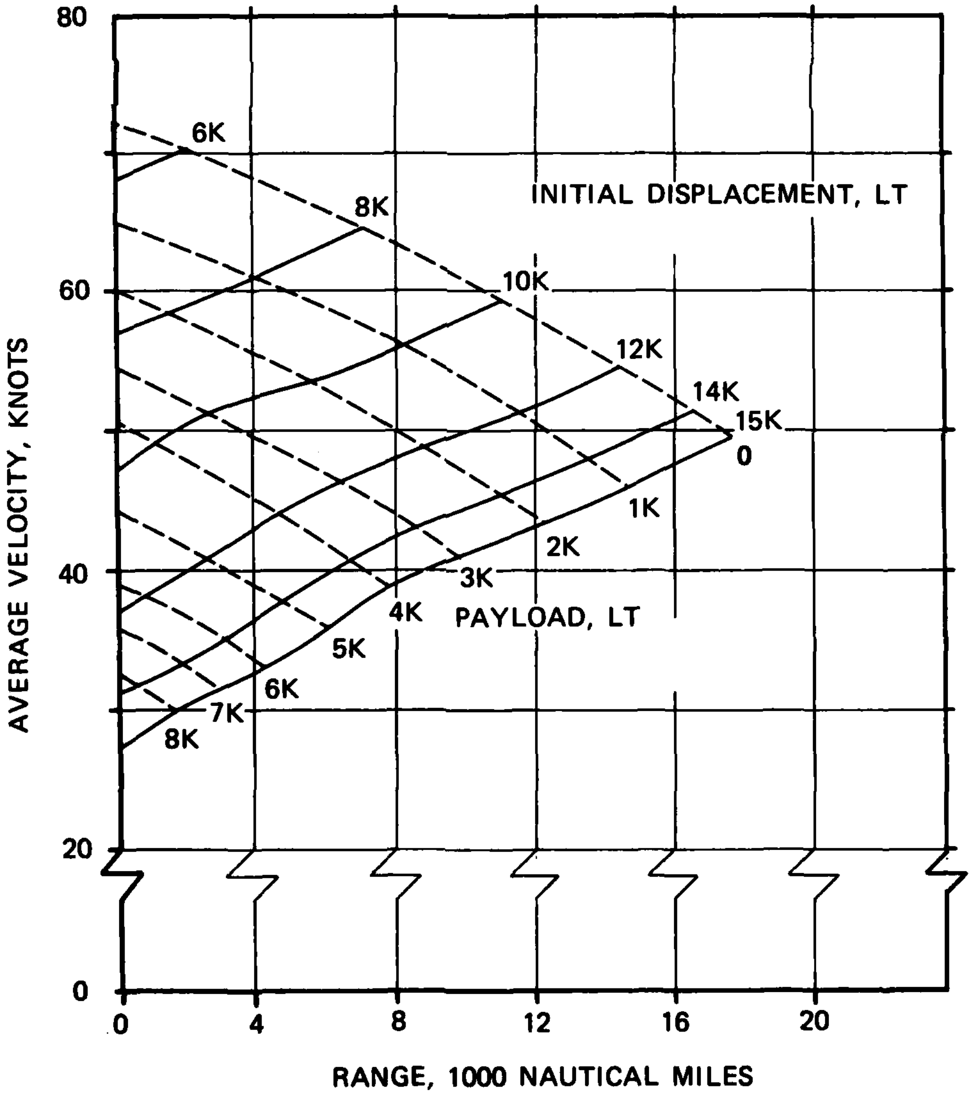


FIGURE 2–2

PAYLOAD VS RANGE AT DIESEL POWER (14,000 SHP), HULLBORNE IN SS 3 (SPEED 14-16 KNOTS)

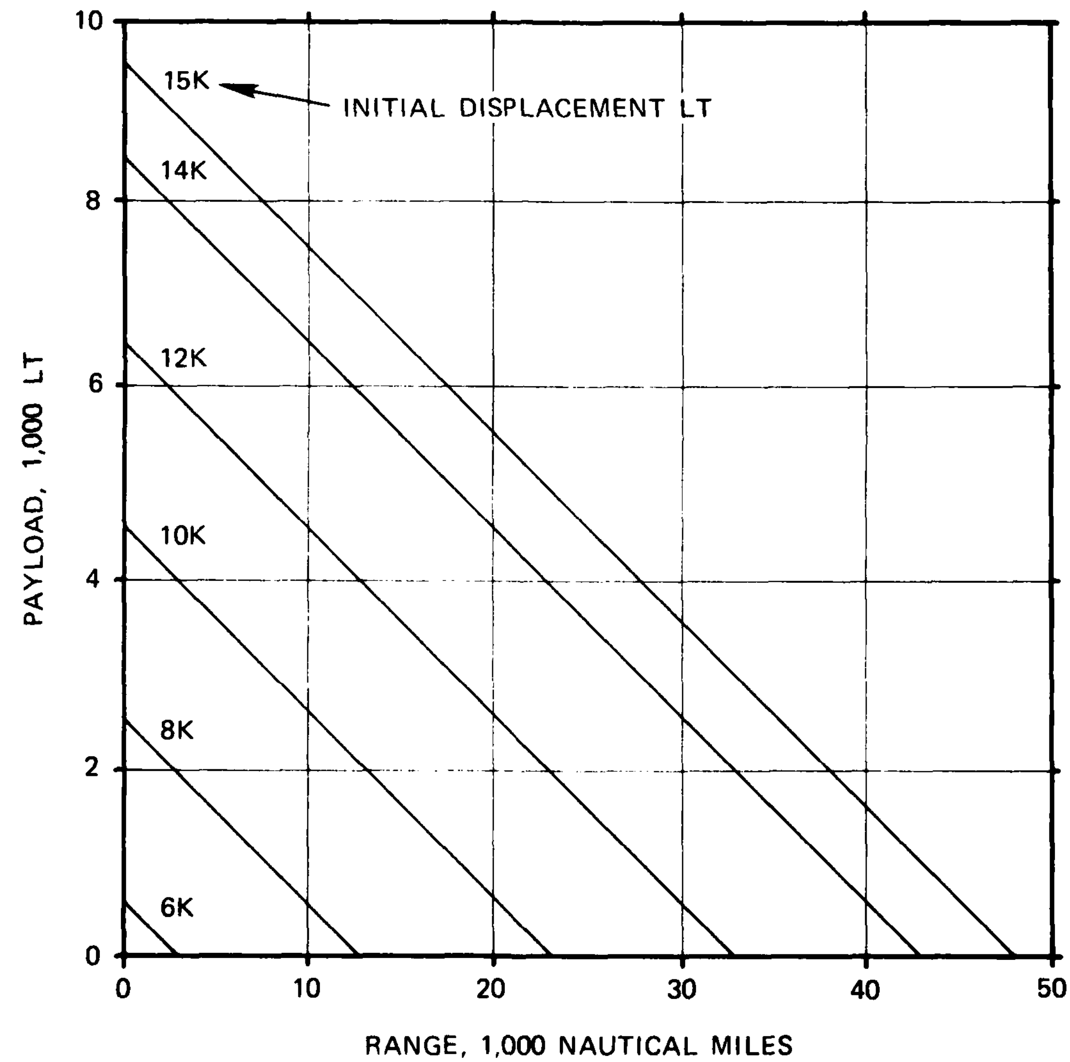


FIGURE 2–3

COMPARISON OF MPS WITH OTHER CONTAINERSHIPS

COMPANY SHIP'S NAME	OCL LIVERPOOL BAY	SEALAND SEALAND VENTURE	NEDLLOYD NEDLLOYD DELFT	SEATRAIN EUROLINER	SEALAND SL-7	MPS
LENGTH	900.0	675.0	839.67	733.04	880.5	686
BEAM	105.83	95.0	105.75	98.42	105.5	105
DEPTH	80.71	54.0	82.00	63.00	64.0	75
DRAFT	36.00	32.13	34.94	32.50	34.8	30.4
V_s	26	22	27	26.4	33.0	38
CB^3	0.595	.593	-----	0.534	0.540	-----
$V_s/\sqrt{L}$	0.867	.847	0.907	0.994	1.112	1.45
SHP	80,000	32,000	81,100	59,240	120,000	120,000
PROPULSION	STEAM	STEAM	STEAM	GAS TURBINE	STEAM	CODOG
NO. OF EQUIVALENT 20 FOOT CONTAINER UNITS	2,300	1,204	2,356	1,632	1,974	1,270*
LIGHTSHIP	23,870	12,327	-----	12,636	26,671	5,388
DEADWEIGHT	34,020	22,432	33,300	23,382	27,144	9,612
DISPLACEMENT	57,890	34,759	-----	36,018	51,815	15,000
CUBIC NUMBER ("cube tons")	76,874	34,628	76,801	45,762	59,451	30,700
LIGHTSHIP/CUBIC NO.	0.311	.355	-----	.276	.416	-----
L/D	11.151	12.500	10.801	11.715	13.758	9.15
L/B	8.504	7.120	8.375	7.499	8.346	8.52**

* Maximum number of 20-foot containers that can be stowed for total payload of 6200 LT.
** This is effective cushion length to beam; overall is 6.53.

TABLE 2-i

Seakeeping capability is excellent with high speed operations in Sea State (SS) 6 contemplated. Simple ride control systems (which modulate cushion pressure) would provide a very comfortable ride in heavy seas.

2.4 APPLICATIONS

With the ship characterized as described, the study team tested the practicality of the concept in a real world requirement, viz, transport of military hardware and materials. A Roll-on/Roll-off (RO/RO) transport configuration was designed and carefully investigated. The bulk of this report deals with a technical disclosure and the conceptual design of the MPS in this configuration.

It was found that the MPS RO/RO is a very capable vessel able to carry 20% of an armored division on a typical 3900 nm transit at an initial speed of 33 knots outward bound and returning empty at 68 knots for an average of about 50 knots round trip. The same ship can carry more than 50% of an airborne division the same distance at 38 knots outgoing and 68 knots return for an average of 53 knots round trip. Many other load-out payload/range/speed alternatives exist and are discussed in later sections.

The unique speed/payload relationships also enhances the ship's ability to deliver large quantities of cargo over an extended period by making empty return transits at 60-70 knots. It was also found that the ship's unique ability to change draft at will makes it very flexible in its ability to accommodate harbor and pier variations. Experiments to determine the feasibility of off-loading directly onto a beach are being conducted with the XR-1D and XR-5.

2.5 SHIP DESCRIPTION

Figure 2-4 presents a schematic of the ship showing the basic size, shape, and features, as well as describing the principal characteristics in tabular form and Table 2-ii summarizes the major weight categories by the Ship Work Breakdown Structure (SWBS) format.

2.5.1 Compartmentation and Arrangements

The MPS RO/RO has six decks, suitable for cargo storage (See Figure 2-5). The design specifically utilizes a rectangular hull configuration which contains large payload areas unobstructed by machinery space intrusion into the cargo decks. The clear cargo storage volume contains 2,476,900 cubic feet. In general, hull access for cargo handling of roll-on/roll-off vehicles and containerized cargo is provided by loading through the sidehulls forward and aft ramps -- either port or starboard. In addition, five stern ramps provide 10 cargo loading lanes. The MPS also incorporates a two-level deck house arrangement. The ship's decks are designated as follows:

02 Level - Pilot House

01 Level - Pilot house, command center, masters' quarters and accommodations for 48 passengers.

PRINCIPAL CHARACTERISTICS

WEIGHTS:

Full Load Displacement (FLD) (LT)	15,000
Empty Weight [illegible] (LT)	5,428
Fuel + Payload (LT)	9,572

DIMENSIONS:

Length Overall (L_{OA}) (ft)	686
Beam Overall (B_{OA}) (ft)	105
Wet Deck Height	33
Cushion Pressure (PSF)	680
Effective Cushion Length (ft)	639
Effective Cushion Beam (ft)	75
L_c/B_c	8.52
Cushion Area (ft^2)	47,900
Main Deck Height (ft)	75
Maximum Navigating Draft (Incl. Rudder) (ft)	35
Mast Height ABL (ft)	110

POWER PLANTS:

Propulsion Engines (CODOG)	Four LM 2500 or 2 SACM diesels (part of lift system)
Propulsors	Four controllable pitch propellers
Lift Engines	Six SACM diesel engines
Lift Fans	Six mixed flow fans

CONSTRUCTION:

Structure	Welded high strength steel
Seals	Two dimensional bag and finger
Electrical	Two 1200 KW 60 Hz diesel generators
Steering	Twin rudder, differential thrust reversal with the propellers and bow thrusters

CREW AND PASSENGER ACCOMMODATIONS IN RO/RO CONFIG:

Crew	38 Officers and men
Passengers	48

CARGO SPACE AND WEIGHT IN RO/RO CONFIGURATION:

Cargo Deck Area (ft^2)	235,000
Cargo Volume (ft^3)	2,476,900

4 1/2 miles of Vehicle Lanes

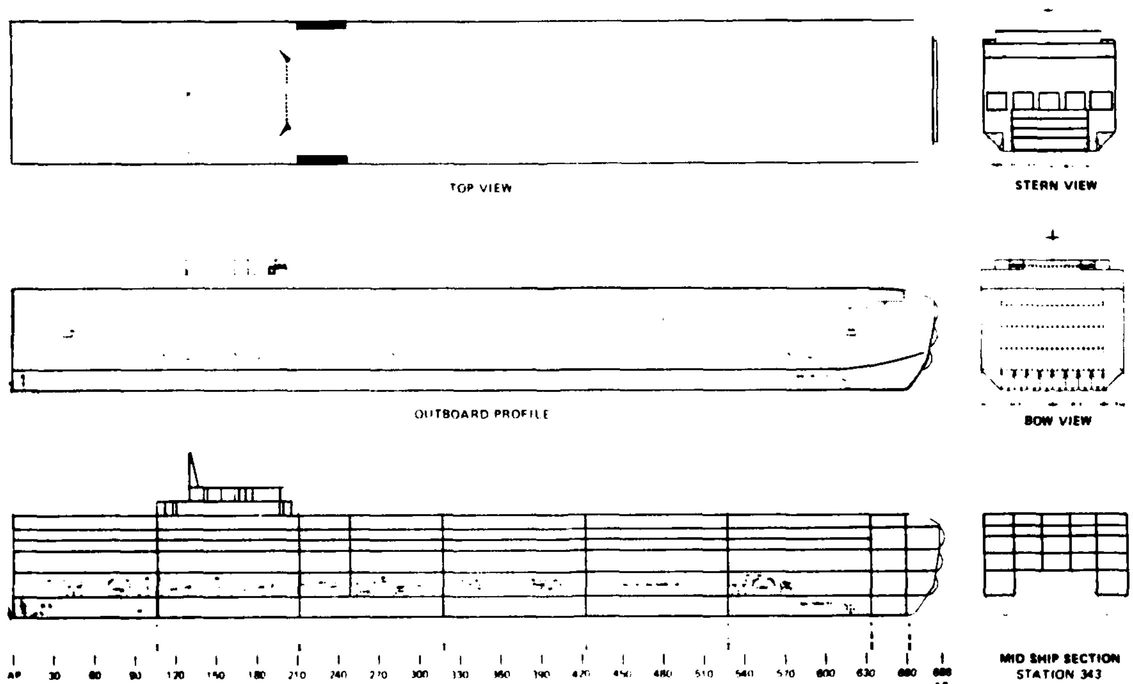


FIGURE 2–4

1st Deck - Main deck house with accommodations for a crew of 38 officers and men. This deck also contains the crew's mess, crew lounge, officer's lounge, wardroom, etc. and also has a cargo area of 35,800 square feet.

2nd Deck - Continuous cargo deck with an area of 60,362 square feet.

3rd Deck - Portable deck with deck area of 44,652 square feet.

4th Deck - Portable deck with a deck area of 62,572 square feet. The forward lift fans with their diesels are located between stations 634 and 681.

5th Deck - Tank deck with a deck area of 63,097 square feet.

6th Deck - Machinery deck contains the main propulsion machinery, aft air cushion fans, auxiliaries, shops, storage and extended range fuel tanks.

MPS - WEIGHT ESTIMATES (LONG TONS)

SWBS GROUP	DESCRIPTION		
100	Structure	3917	
200	Prop.	255	
300	Electric	95	
400	Comm. & Surveillance	23	
500	Auxiliary	266	
567	Lift System	284	
600	Outfit and Furnishings	293	
700	Armament	None	
Design and Builders Margin		255	
Growth Margin		0	
LIGHT SHIP			5388
Personnel		5	
Prov. Person Stores - General		8	
Lube Oil Hydraulic		14	
Potable Water		13	
			40
Cargo		5950	
Removable Decks		188*	
Tie Downs		313	
PAYLOAD			6451
Fuel			3121
TOTAL (FLD)			15,000

*Removable deck required to fill ship to 15,000 tons with armored equipment.

TABLE 2-ii

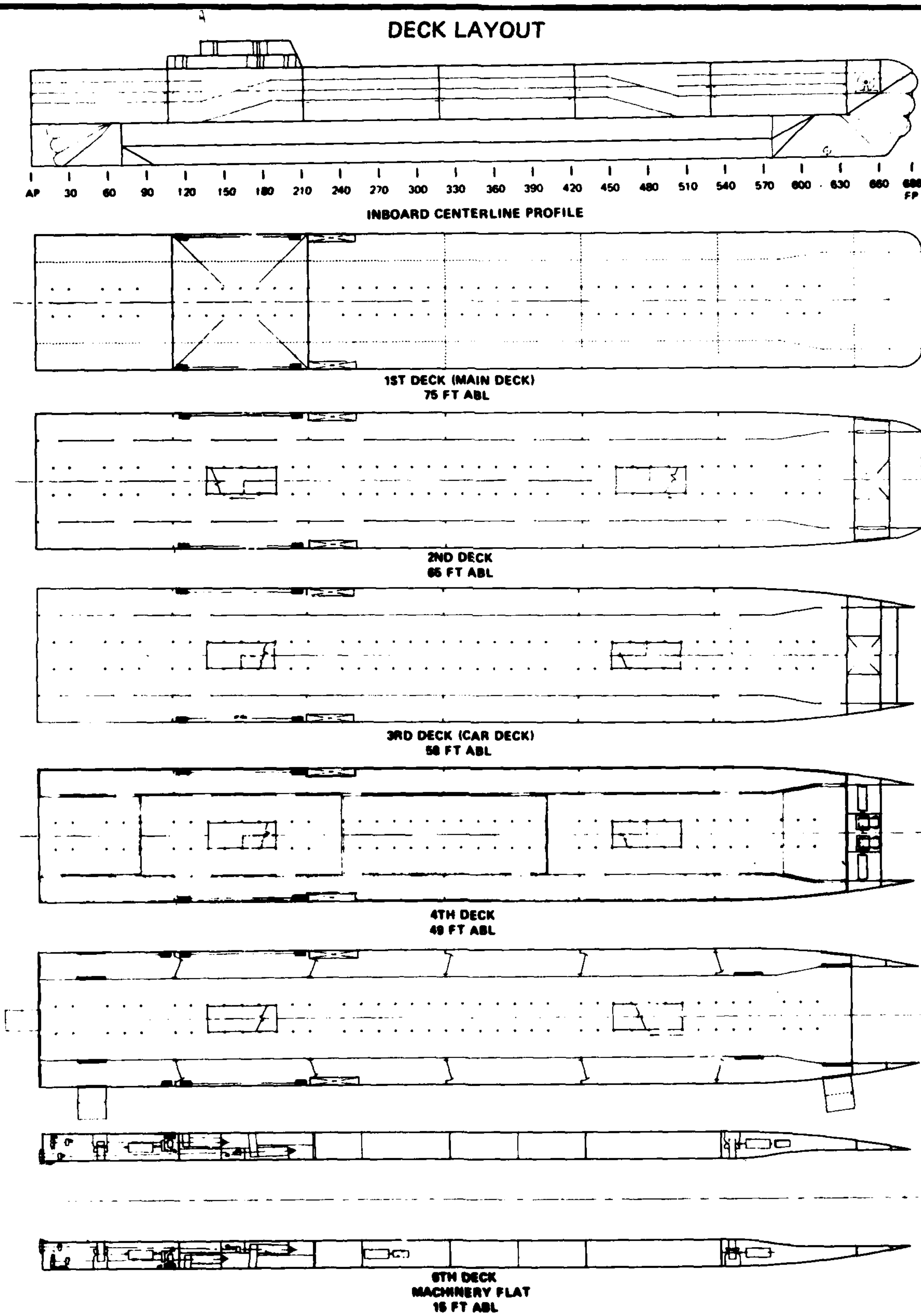

DECK LAYOUT
AP 30 60 90 120 150 180 210 240 270 300 330 360 390 420 450 480 510 540 570 600 630 660 686 FP
INBOARD CENTERLINE PROFILE
1ST DECK (MAIN DECK)
75 FT ABL
2ND DECK
65 FT ABL
3RD DECK (CAR DECK)
58 FT ABL
4TH DECK
49 FT ABL
6TH DECK
MACHINERY FLAT
15 FT ABL

FIGURE 2–5

2.5.2 Lift and Propulsion System

The lift system, comprised of six SACM diesel engines running six 6000 cfs industrial type mixed flow fans, provides the low pressure high volume air flow which creates the air cushion supporting the ship in cushionborne operations. The cushion is sealed forward by a rubberized fabric seal of the common bag and finger type and aft by a common multi-lobe rubberized fabric seal. These types of seals have seen successful and reliable world-wide service in various air cushion vehicles.

Two of the fan diesels are connected to the outboard shafts for propulsion in a combined diesel or gas turbine (CODOG) arrangement with LM-2500 gas turbine propulsion engines. The purpose of this arrangement is to provide low powered, up to 15 knots, economical operations in the hullborne mode. Very long ranges and high endurance result from this arrangement. Four LM-2500 gas turbine engines, each coupled to a shaft, provide for the higher power requirements of various missions (hullborne and cushionborne).

2.5.3 Other Systems

The ship is provided with a Navigation and Collision Avoidance System (NAVCAS), an Exterior and Interior Communications System, and a Ship Control System. Electrical power is provided by either one of two 1210 KW diesel driven generators, one diesel dedicated to a generator, the other assignable from the lift fan system for emergency purposes. A suitable distribution is provided. Auxiliary machinery, including pumping systems, distilling plants, sewage disposal system and air conditioning are installed in the sidehulls between frames 250 and 317.

2.5.4 Outfit and Furnishings

The pilot house, radio room and navigation support areas are on the centerline of the 01 level. This central location and height of the pilot house are comparable with high speed operations when underway.

Living, working, service and storage space are located in the main deck house. The galley, crew mess, supporting reefer and associated spaces are also located near the centerline area of the deck house. This central location provides a separation of the unlicensed (enlisted) accommodations to the port side of the deck house and the licensed (officer) accommodations to the starboard.

Workshops are located in either sidehull on the machinery deck about mid-ship. Repair parts and general storage (flammable liquids) are also on this level. Ladders, located aft of the engine intakes, lead to the cargo and engineering spaces below.

2.6 CARGO STOWAGE AND HANDLING

The MPS offers large structurally clear areas for cargo stowage and excellent access for cargo handling. Main access for the loading and unloading of mobile cargo is provided by aft side ramps and forward side ramps (both port and starboard), together with five double lane stern ramps. Hatch openings with flush

fitting hatch covers could be provided through the main deck for crane handling of non-mobile cargo.

Internally, ramps are provided for roll-on/roll-off or for fork lift operations between deck levels. Minimum bulkheads are provided to facilitate internal cargo movement. Portable cranes may be used on the weather deck for handling cargo over the side. The lift fans can be used to match the stern ramp heights to most pier heights. The stern ramp can be lowered below the waterline to allow an amphibious vehicle to enter or leave the tank deck. The ramp can also be adjusted to permit vehicles to drive on or off small lighters.

2.7 MILITARY LOAD CAPABILITY

The payload stowage areas provide the capability for internal stowage of the vehicular equipment for 20% of an armored division plus 337 LT of support equipment, petroleum, oil and lubricants (POL), repair parts, or miscellaneous supplies for a 3900 nm ocean transit. Alternately, the payload storage area provides the capability to internally stow the aircraft and wheeled vehicles for 50% of an airborne division plus 3634 LT of equipment, POL, repair parts, or miscellaneous supplies for the same 3900 nm ocean transit. See Table 2-iii for typical loadout conditions. The MPS has a volume capacity for 548 standard 40 foot containers or 1270-20 foot containers and a weight capacity for 413-40 foot containers (15 LT each) or 563-20 foot containers (11 LT each). The containers may be loaded or off-loaded by means of straddle loaders in the roll-on/roll-off mode or by shore-side cranes for main deck stowage. Palletized or break bulk cargo can be similarly handled using fork lift trucks or low bed trailers for roll-on/roll-off operation.

2.8 SHIP DELIVERY

From go ahead for an MPS Program, the initial ship would be available within 51 months. This assumes that the required preliminary design would be completed by the Government within nine months.

During this preliminary design period, preparation of an RFP will begin. The RFP will be for the design and construction of a lead MPS with follow-on production runs in one yard of either 6 or 13 ships. The RFP will be released one month after completion of preliminary design with an award for design and construction of the lead MPS made five months after release of the RFP. For planning purposes, the 14 ship program is expected to be split between two shipyards, although the entire program could be awarded to a single yard.

The design and construction of the lead MPS will require 36 months in each yard with follow production ships constructed over 30-month spans. Construction of the 1st production ship will begin nine months after design and construction of the lead ship and subsequent follow ships will begin at three-month intervals with the Lead MPS in each yard delivered at Month 51 after go ahead.

MPS – SUMMARY OF PERFORMANCE – CUSHIONBORNE

MPS LOADING	POWER* LEVEL	WEIGHTS - 1000 LT: ID	WEIGHTS - 1000 LT: LIGHT SHIP	WEIGHTS - 1000 LT: PAY-LOAD	WEIGHTS - 1000 LT: FUEL OUTWARD	WEIGHTS - 1000 LT: FUEL RETURN	NOMINAL CUSHION PRESSURE ID-psf	RANGE NM	SPEED - KNOTS IN SS 3: CONDITION 1	CONDITION 2	CONDITION 3	CONDITION 4	AVERAGE OUT	AVERAGE RETURN
ARMORED	NP	12.2	5.4	4.3	2.5	1.3	556	3900	33.0	45.0	62.0	70.0	39	64
ARMORED	MP	12.2	5.4	4.3	2.5	1.3	556	3900	36.5	49.0	65.0	72.0	44	67
AIRBORNE	NP	[illegible]	5.4	[illegible]	2.2	1.3	500	3900	38.5	49.0	57.0	70.0	43	64
AIRBORNE	MP	[illegible]	5.4	[illegible]	2.2	1.3	500	3900	41.0	53.0	60.0	[illegible]	47	67
MAXIMUM DISPLACEMENT	NP	[illegible]	5.4	[illegible]	[illegible]	[illegible]	[illegible]	3900	24.0	35.0	60.0	70.0	31.5	64
MAXIMUM DISPLACEMENT	MP	[illegible]	5.4	6.2	[illegible]	1.3	680	3900	[illegible]	38.0	[illegible]	72.0	33.5	67

CONDITIONS

1 - Light ship + payload + full fuel (ID)
2 - Light ship + payload + zero (0) fuel
3 - Light ship + zero (0) payload + full fuel (return)
4 - Light ship + zero (0) payload + zero (0) fuel
NP - Normal Rated Power = 108 KHP
MP - Mission Rated Power = 120 KHP

TABLE 2–iii

3. SHIP PERFORMANCE

3.1 GENERAL

The performance relationships of an SES are a function of ship's weight, power and sea state; i.e., ship speed increases as fuel load, payload or sea state decrease and/or the propulsive power is increased. Since an infinite number of these conditions can be postulated for a specific point design, the performance is discussed in a general sense under a variety of specified conditions. This approach best shows the wide selection of speed, payload, range and fuel economy available to the MPS operator. One performance table and twenty one graphs illustrate many of the operational options.

The graphical data include both cushionborne and hullborne conditions at various propulsive power levels. Power variation is achieved by operating the turbines either singly or in several combinations at the individual power setting of 27,000 hp per unit. Data are also presented for all four turbines operating at their mission power rating of 30,000 hp and for the two CODOG diesels operating at a total of 14,000 hp. Propulsion thrust lines, used in these graphs, were calculated from information presented in the Propulsion Section.

In general, the MPS can operate in calm water at mission power at approximately 73 knots at a light ship weight of 5400 long tons (LT); however, when loaded to 15,000 LT, the initial speed is about 30 knots, with speed gradually increasing as the voyage progresses and fuel is expended. More specifically, the performance characteristics of the MPS under six different conditions covering displacement from 5400 LT to the full load displacement of 15,000 LT are shown in Table 2-ii.

Estimates of full-scale drag are based on analytical methods that have been correlated with model data up to 12,000 LT, Figure 2-1. For heavier displacements, the predictions are based on conservative extrapolations of the model data.

The lift power associated with the drag curve, as a function of speed, in sea state 3 (SS-3) for various displacements is shown in Figure 3-1. The MPS mission rating line is the upper boundary of the ship operating envelope and represents the maximum lift needs for this sea state. A comparison with the maximum installed lift horsepower shows that there is considerable surplus power, and for much of the ship's operation in low sea states only half of the installed power is required. The total installed power is required in higher sea states for both drag reduction and ride control.

OPTIMUM LIFT POWER VS VELOCITY IN SS–3
FOR VARIOUS DISPLACEMENTS

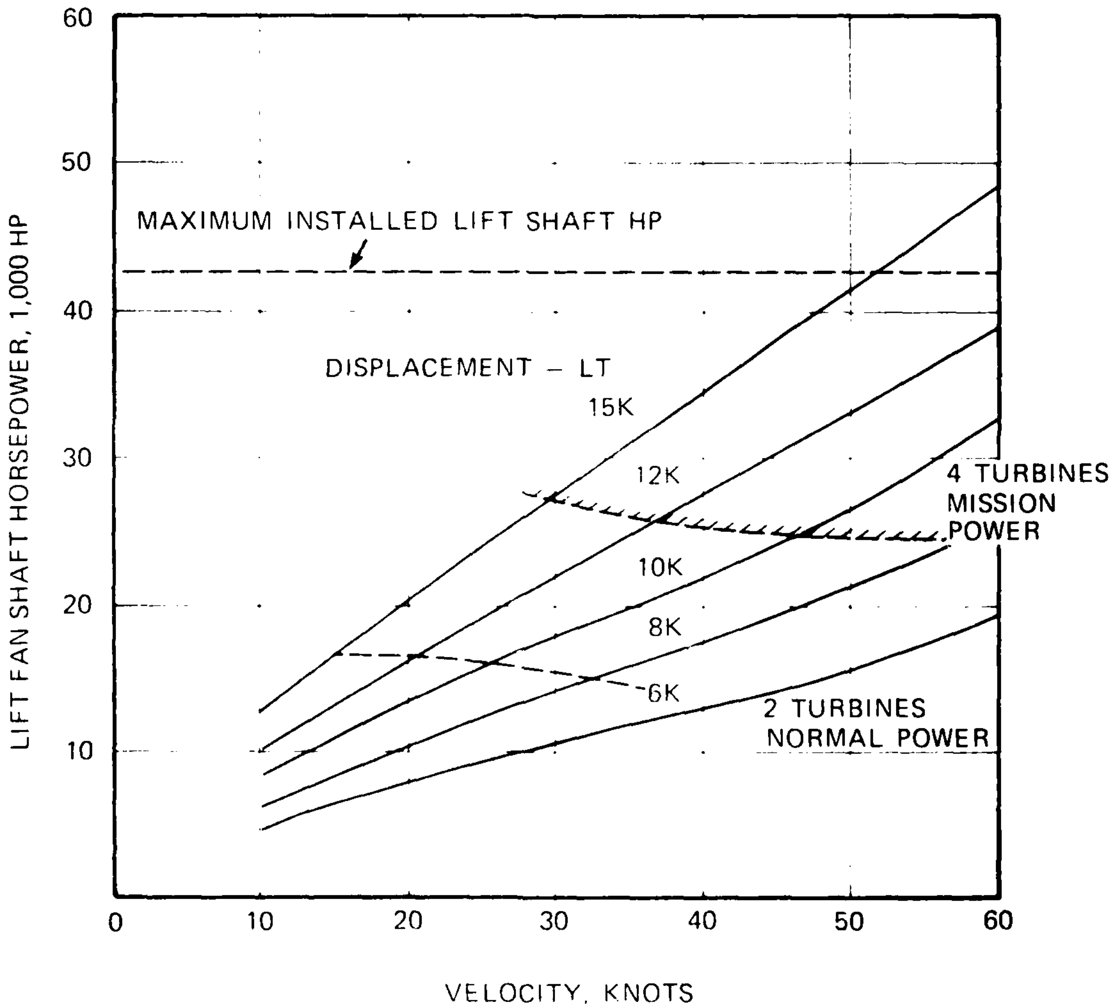


FIGURE 3–1

3.2 THRUST, DRAG, AND SPEED

3.2.1 Cushionborne

Figure 2-1 shows six thrust curves for various power levels and seven drag curves for various gross weights from 5,400 LT to 15,000 LT (FLD), vs. velocity in SS-3. (Drag calculations have been made for other sea states up to and including SS-6). The distinctive high hump drag in the curve, typical of low L_c/B_c SES, no longer exists at the lower speeds of the high L_c/B_c ship, even at FLD. Except for the small secondary hump condition in the 20-25 knot region, the MPS, a high L_c/B_c ship, always operates sub-hump.

The effect of ship's displacement on speed is obvious and demonstrates how the MPS can take advantage of reduced load (by burning off fuel or returning empty). For example, at FLD and normal power the ship has an initial speed of about 25 knots. The same ship at 5400 LT will have a speed of 70 knots. This unique performance trait can be compared with conventional cargo ships which characteristically operate at essentially constant speed from FLD to light ship condition regardless of the power level.

The variation of ship's speed as a function of two power settings, i.e., normal power rating (108,000 hp) and mission power rating (120,000 hp) is shown on Figures 3-2 and 3-3, respectively; the effect of the higher power is to increase speed by approximately two to three knots over the full range of displacements.

The influence of sea state on speed for a ship of this displacement is fairly small up to about mid-SS-5 (10 feet significant wave height), beyond which the speed reduction for all displacements is on the order of 8-10% relative to calm water. For mid-SS-6 (15 feet significant wave height) the percentage speed reduction is more significant and is dependent on the ship's displacement. (See Appendix D for table describing wave heights).

3.2.2 Hullborne

Figure 3-4 shows curves of thrust and drag of the hullborne ship in SS-3 (4.0 feet significant wave height) and SS-5 (10 feet significant wave height). Data are for displacements of 6,000, 10,000 and 14,000 LT. For other displacements, the information can be obtained with sufficient accuracy by interpolation. As shown on the hullborne mode curves, the ship performs much like a conventional ship with little or no speed variations with displacement. Thus, in SS-3, as the ship displacement decreases from 14,000 LT to 6,000 LT, the speed increases from 23 knots to 27 knots. The effect of sea state is also small; at mission power, the degradation in speed from SS-0 (practically the same as SS-3) to SS-5 is less than 20% for all ship displacements. The low speed operation of the MPS using diesel engines is noteworthy. With only 14,000 hp, the speed in SS-3 varies from 13.5 knots at 14,000 LT to 15.5 knots at 6,000 LT. Operating with only one diesel, speeds between 10-12 knots are possible.

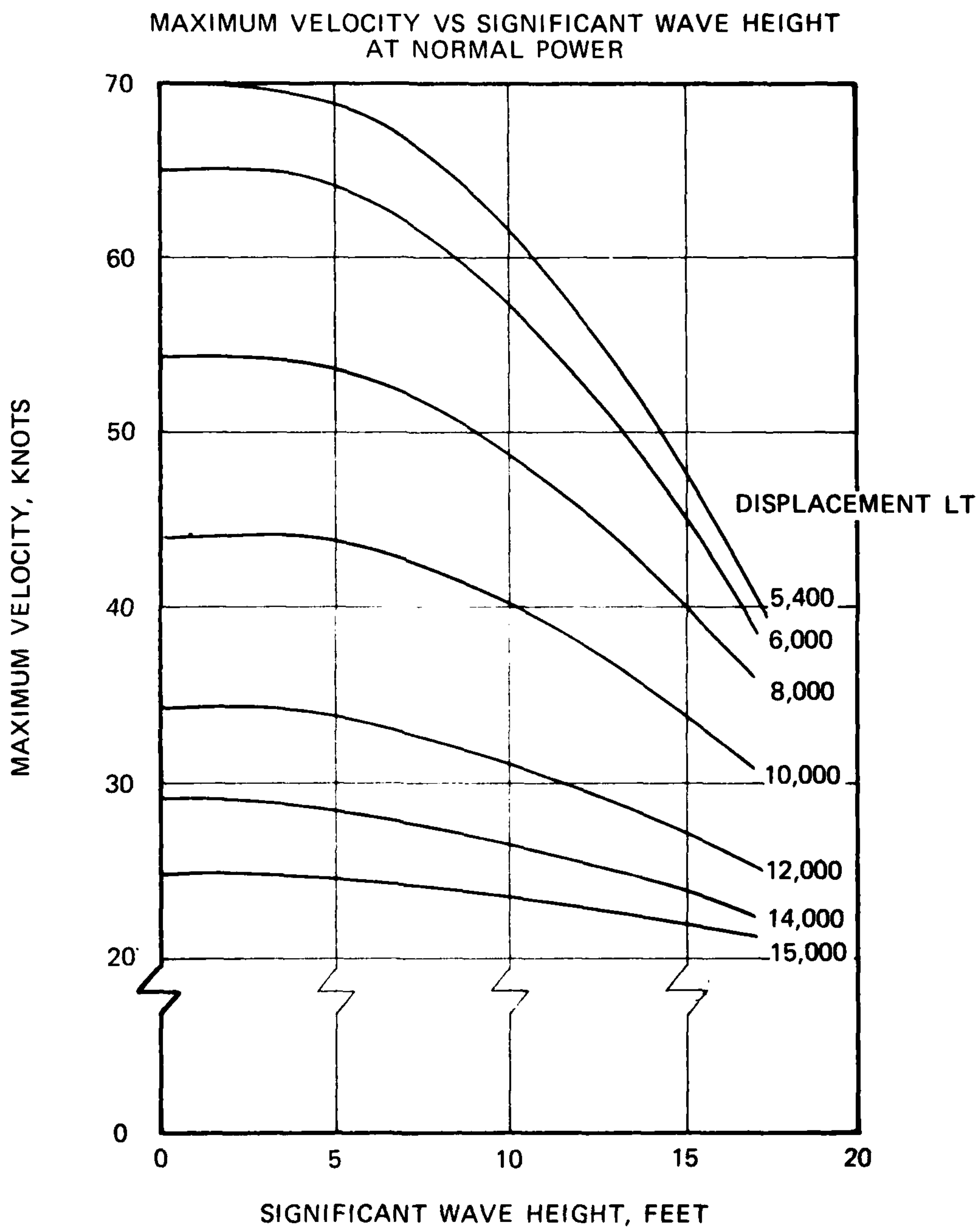

MAXIMUM VELOCITY VS SIGNIFICANT WAVE HEIGHT
AT NORMAL POWER
MAXIMUM VELOCITY, KNOTS
70
60
50
40
30
20
0
0
5
10
15
20
SIGNIFICANT WAVE HEIGHT, FEET
DISPLACEMENT LT
5,400
6,000
8,000
10,000
12,000
14,000
15,000

FIGURE 3–2

MAXIMUM VELOCITY VS SIGNIFICANT WAVE HEIGHT
AT MISSION POWER

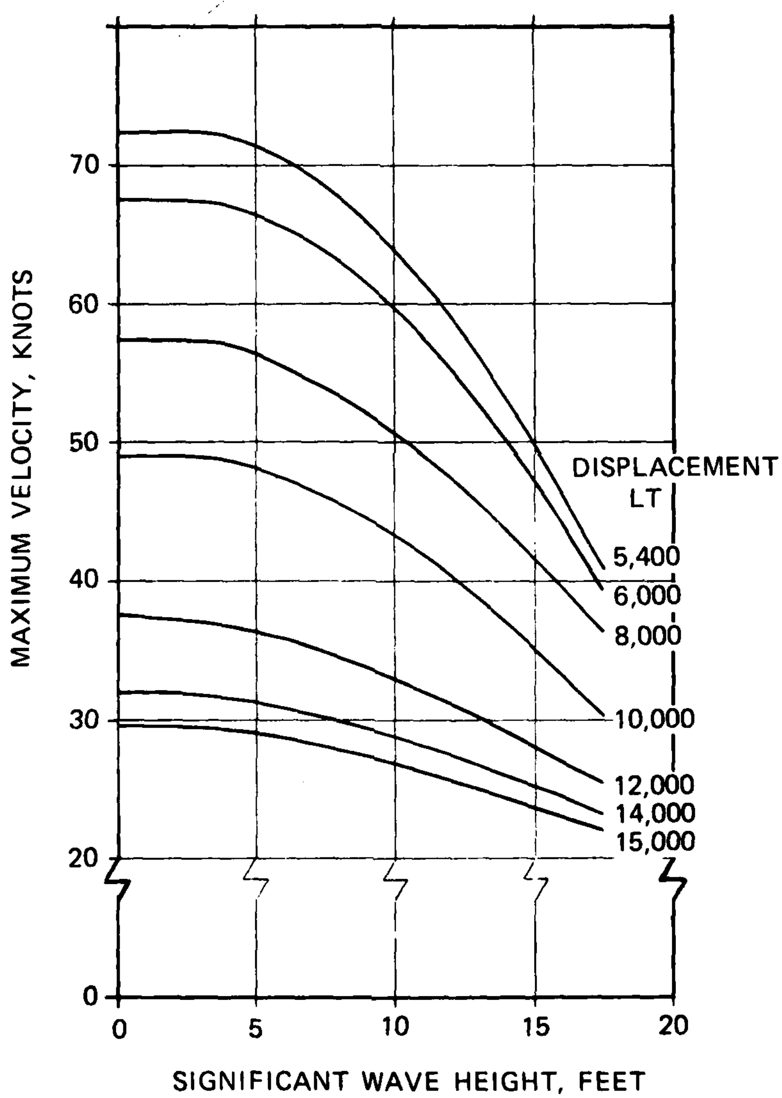


FIGURE 3–3

HULLBORNE DRAG VS VELOCITY,
FOR 6000, 10,000 14,000 LT DISPLACEMENTS

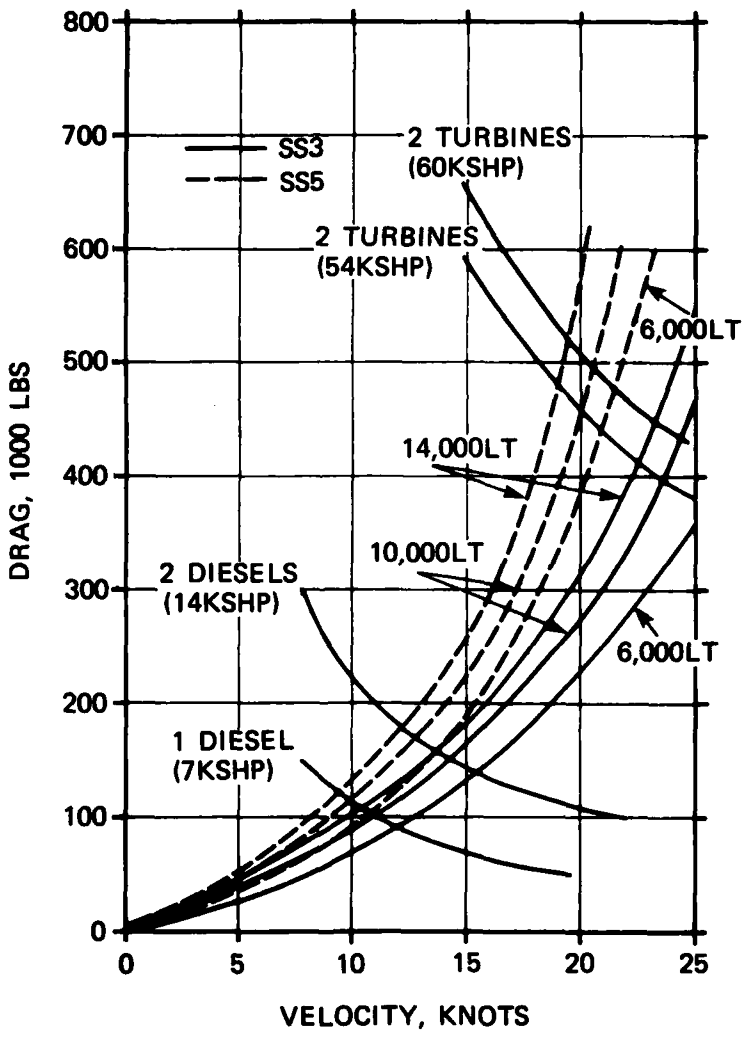


FIGURE 3–4

3.3 RANGE AND PAYLOAD

3.3.1 Cushionborne

Payload versus range is presented in Figures 3-5 and 3-6 for SS-3 and SS-6. These curves are applicable for both normal and mission power ratings, there being no significant difference between the two graphs. The reason for this is that the higher mission power rating is characterized by a lower specific fuel consumption so that the total fuel required in both cases differs only slightly.

Figures 3-7 through 3-12 are convenient for estimating ships' performance such as payload range and transit time under varying conditions of sea state, power and displacement. Figure 3-7 and Figure 3-8 present Velocity vs. Distance Travelled and Velocity vs. Range for the normal and mission power rating and at various displacements from 6,000 LT through 15,000 LT.

For a required range and payload the curves give the initial displacement required and the instantaneous velocities at any point in the distance travelled. The vertical axis gives instantaneous velocity, the horizontal axis distance travelled, the horizontal lines are for constant payload and the inclined lines are for constant displacement.

For example, if a range of 7000 nm, payload of 1,400 LT and displacement of 10,000 LT describes the ship mission profile, then Figure 3-7 shows that for normal power, the instantaneous speed at the end of 7,000 nm is 59 knots. Following along the constant 10,000 LT displacement line, it can be seen that the initial speed was 42.5 knots with intermediate speeds defined according to the distance travelled. Figure 3-9 shows that the average velocity for the 7,000 nm trip at normal power is 51 knots with an endurance of 137 hours as shown in Figure 3-10.

For the mission power rating, Figure 3-8 shows that the starting speed for the 7,000 nm., 1,400 LT payload case is 48 knots, and final speed is 63 knots. The average trip speed is 55 knots as shown in Figure 2-2 and the endurance of 127 hours as shown in Figure 3-11.

The range/fuel required relationship for the displacement considered in the previous example is shown in Figure 3-12. For the 10,000 LT, 7,000 nm case, the fuel required is 3,200 LT. If 1,400 LT of fuel is substituted for payload, the range would be increased to 9,600 nm. The total fuel expended would be 4,600 LT. The curve also shows that fuel consumption increases with increased initial displacement. This is a consequence of the increased hydrodynamic drag with increasing ship displacement -- but drag alone is not an absolute measure of the effectiveness of loading the MPS to any particular displacement. A more useful measure of mission effectiveness is payload times velocity in knots as shown in Figure 3.13, where it is expressed as nautical miles x payload per hour.

PAYLOAD VS RANGE – NORMAL OR MISSION POWER,
CUSHIONBORNE IN SS 3

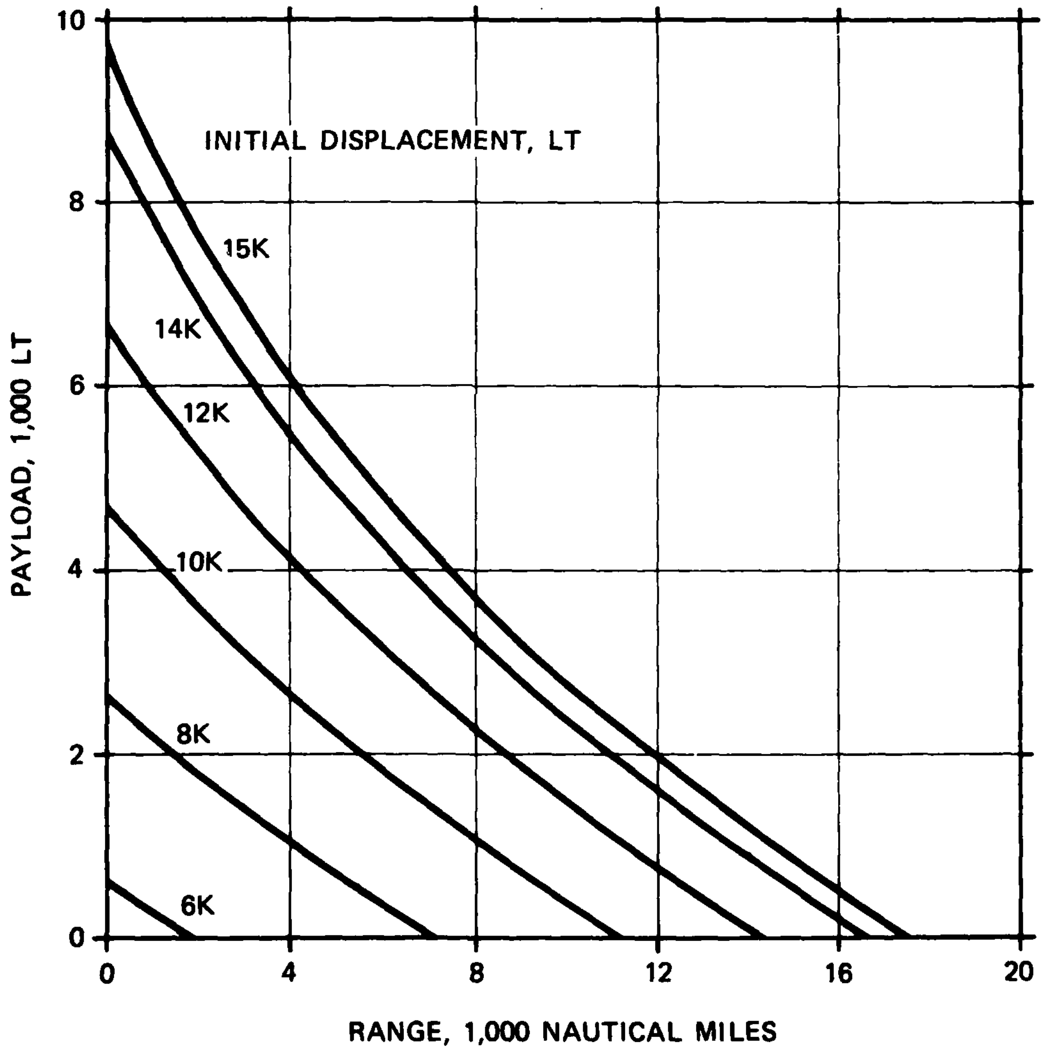


FIGURE 3–5

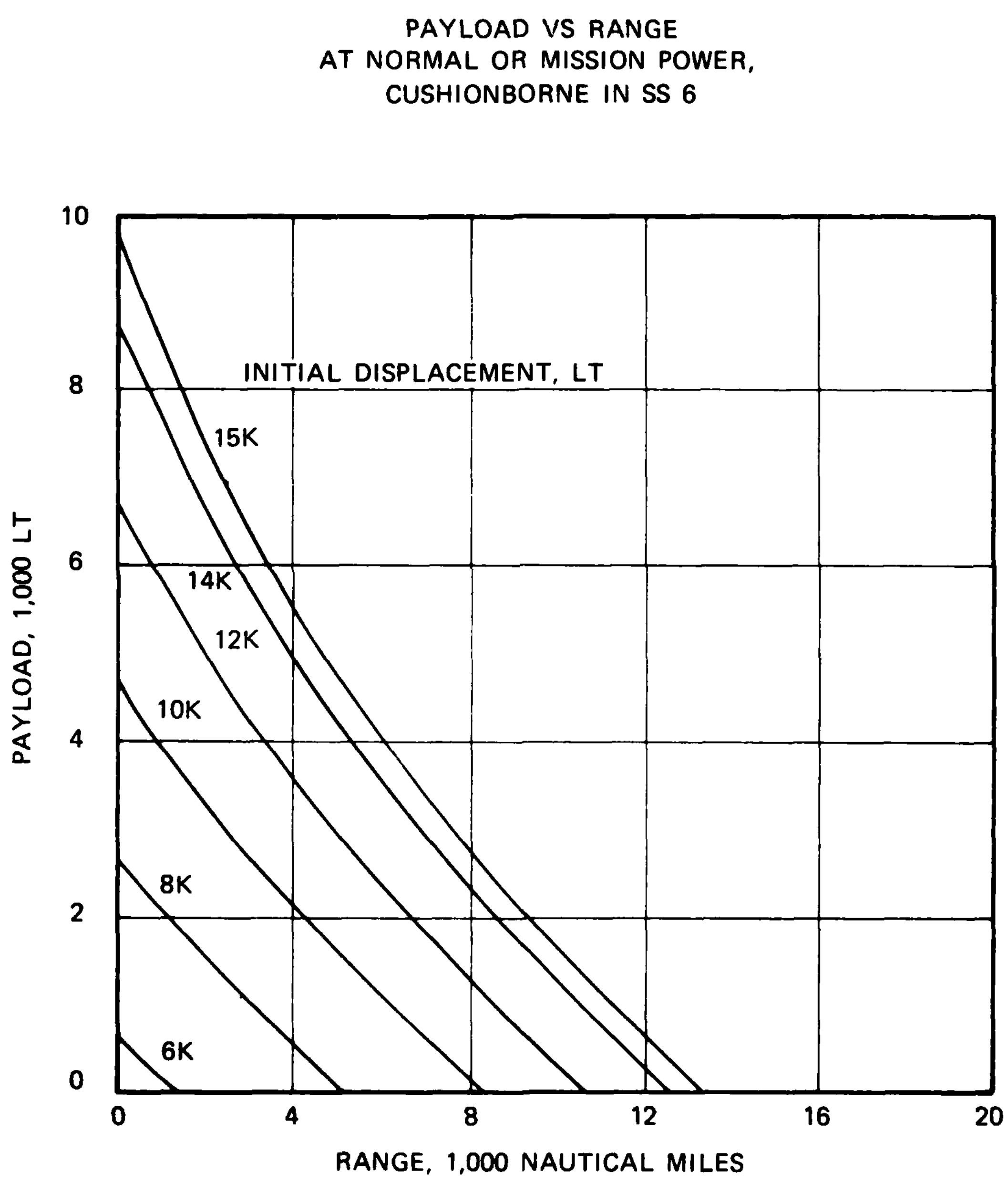

PAYLOAD VS RANGE
AT NORMAL OR MISSION POWER,
CUSHIONBORNE IN SS 6
INITIAL DISPLACEMENT, LT
15K
14K
12K
10K
8K
6K
PAYLOAD, 1,000 LT
0
2
4
6
8
10
0
4
8
12
16
20
RANGE, 1,000 NAUTICAL MILES

FIGURE 3–6

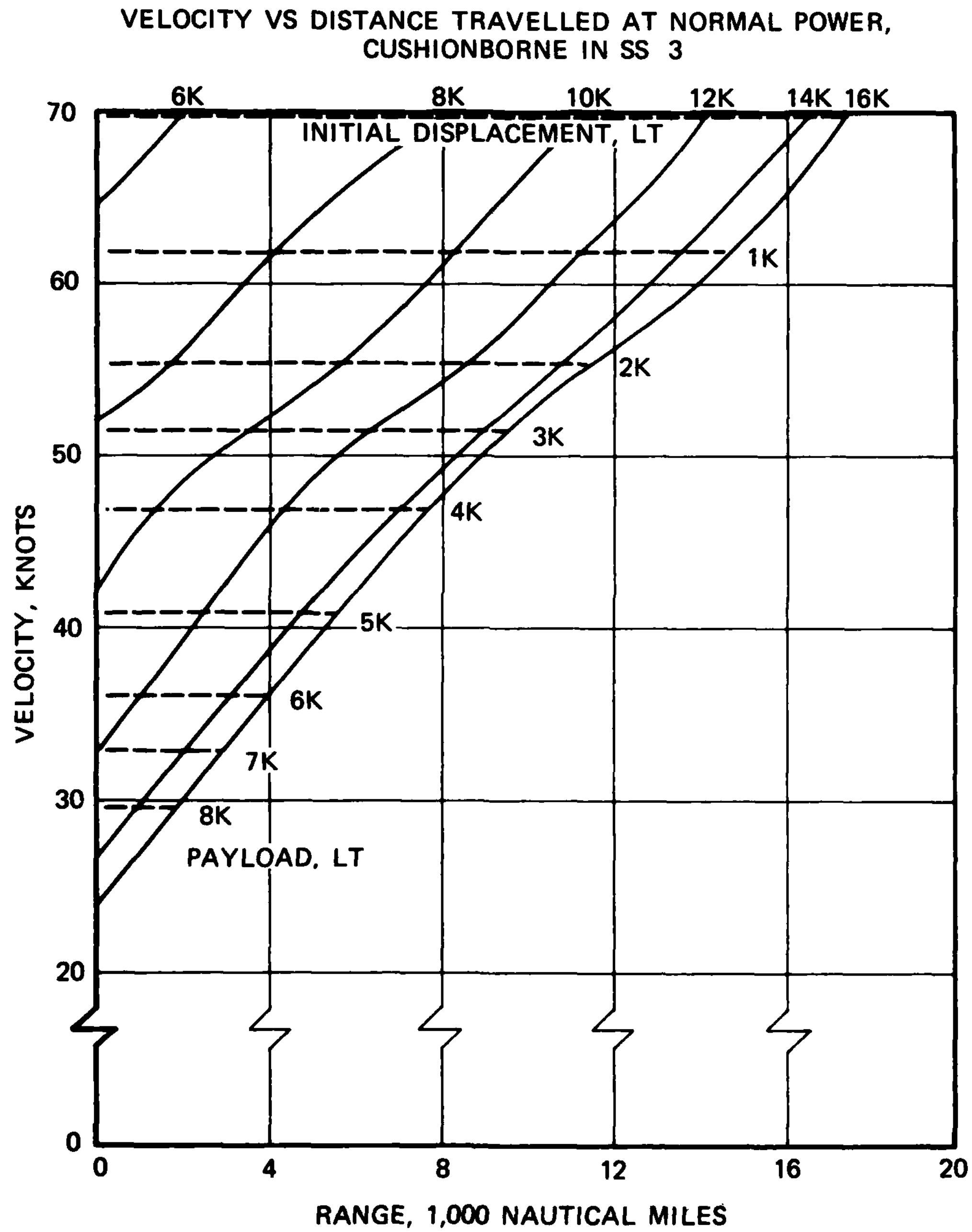

VELOCITY VS DISTANCE TRAVELLED AT NORMAL POWER,
CUSHIONBORNE IN SS 3
INITIAL DISPLACEMENT, LT
6K
8K
10K
12K
14K
16K
PAYLOAD, LT
1K
2K
3K
4K
5K
6K
7K
8K
VELOCITY, KNOTS
70
60
50
40
30
20
0
RANGE, 1,000 NAUTICAL MILES
0
4
8
12
16
20

FIGURE 3–7

VELOCITY VS DISTANCE TRAVELLED AT MISSION POWER,
CUSHIONBORNE IN SS 3

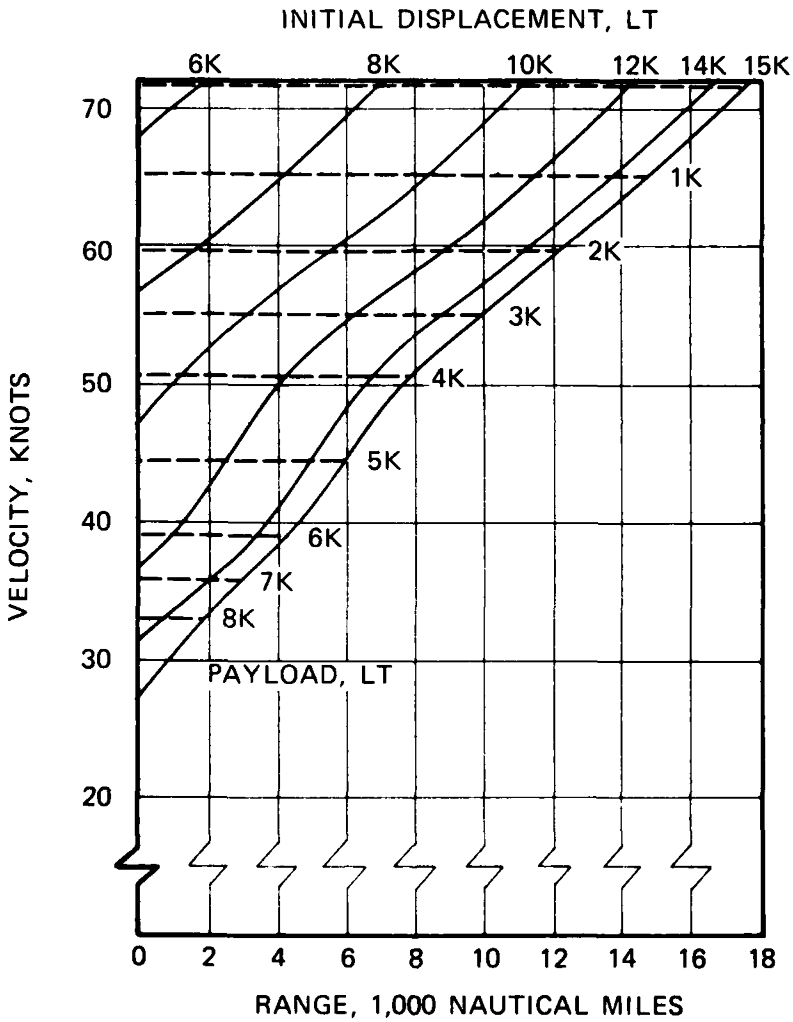


FIGURE 3–8

AVERAGE VELOCITY VS RANGE AT MISSION POWER,
CUSHIONBORNE IN SS 3

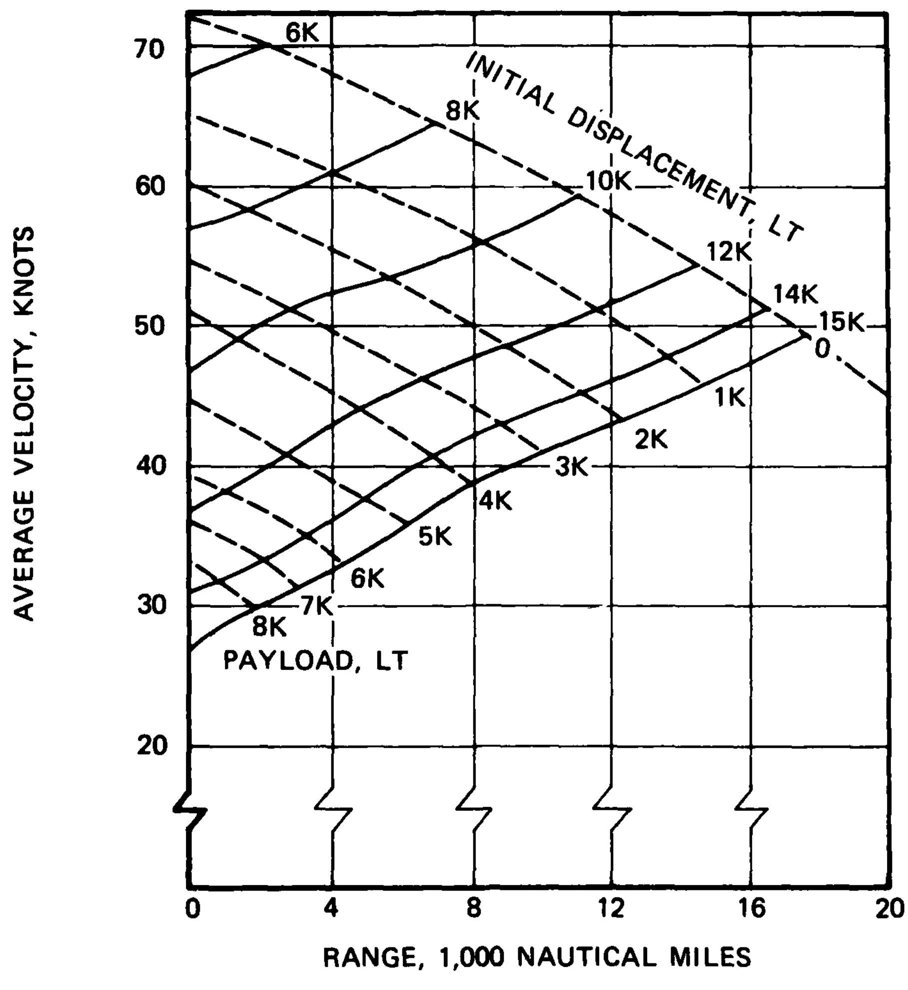


FIGURE 3–9

ENDURANCE VS RANGE AT NORMAL POWER,
CUSHIONBORNE IN SS 3

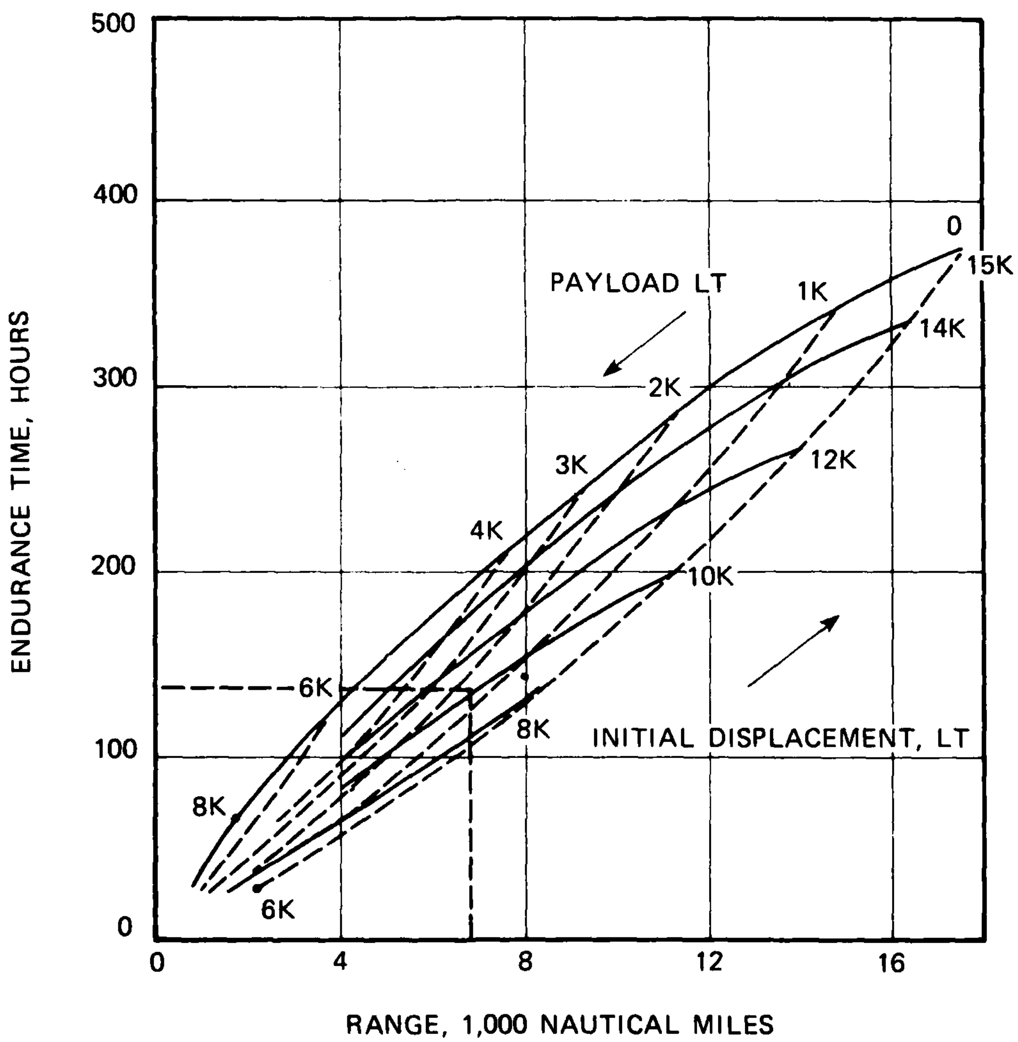


FIGURE 3–10

ENDURANCE VS RANGE AT MISSION POWER,
CUSHIONBORNE IN SS3

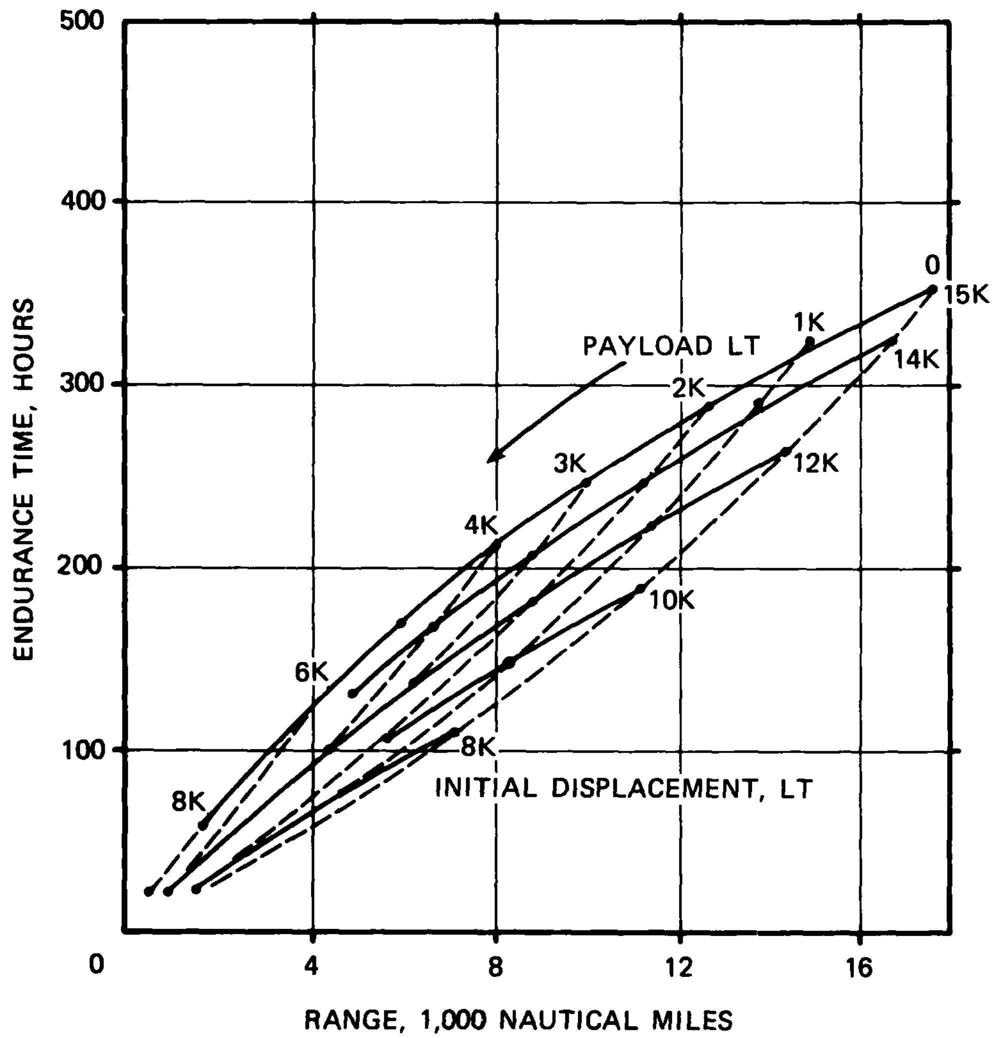


FIGURE 3–11

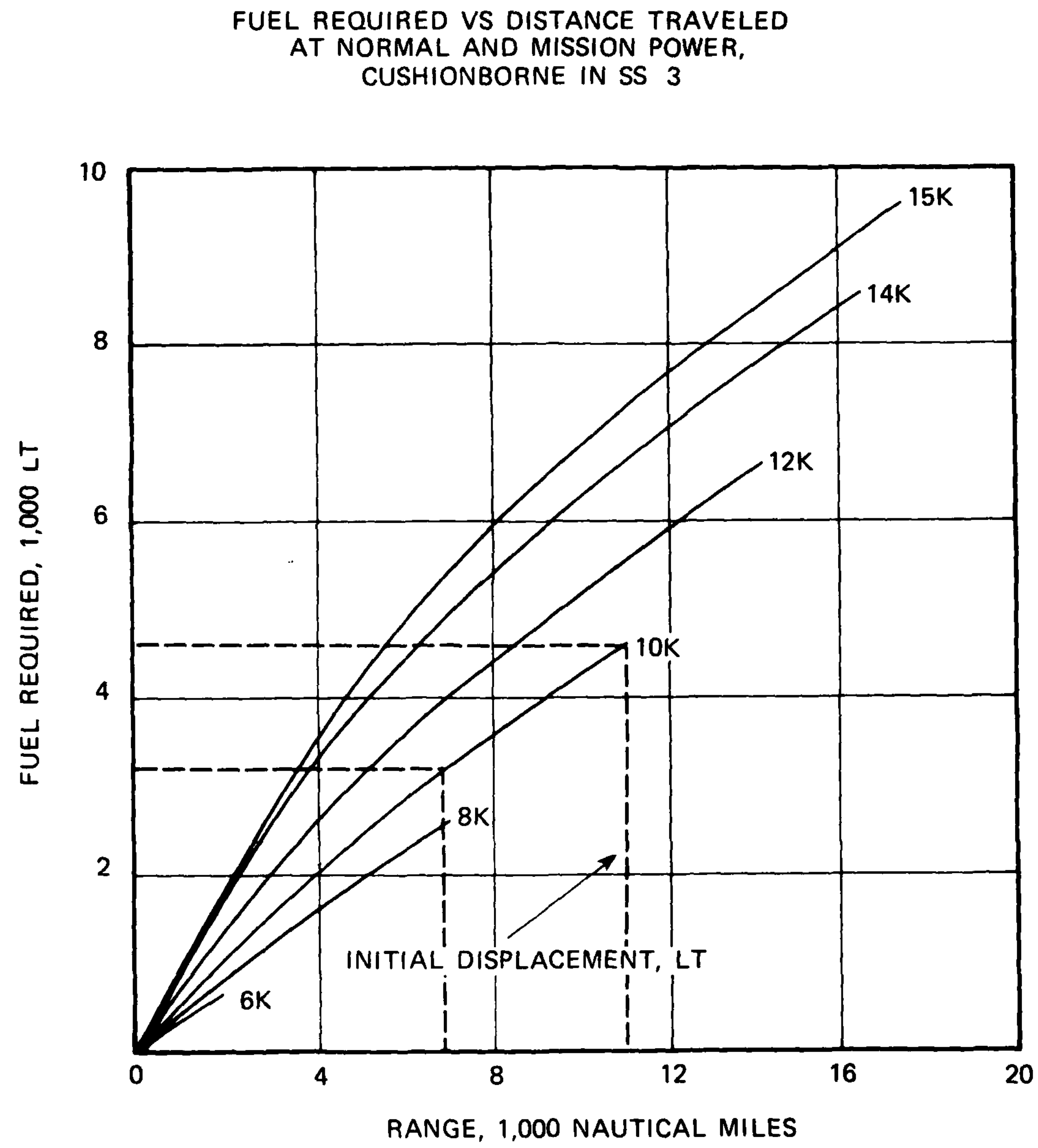

FUEL REQUIRED VS DISTANCE TRAVELED
AT NORMAL AND MISSION POWER,
CUSHIONBORNE IN SS 3
FUEL REQUIRED, 1,000 LT
RANGE, 1,000 NAUTICAL MILES
INITIAL DISPLACEMENT, LT
15K
14K
12K
10K
8K
6K
0
2
4
6
8
10
12
16
20

FIGURE 3–12

PAYLOAD X VELOCITY AS A FUNCTION OF INITIAL DISPLACEMENT, CUSHIONBORNE IN SS 3 AT NORMAL POWER

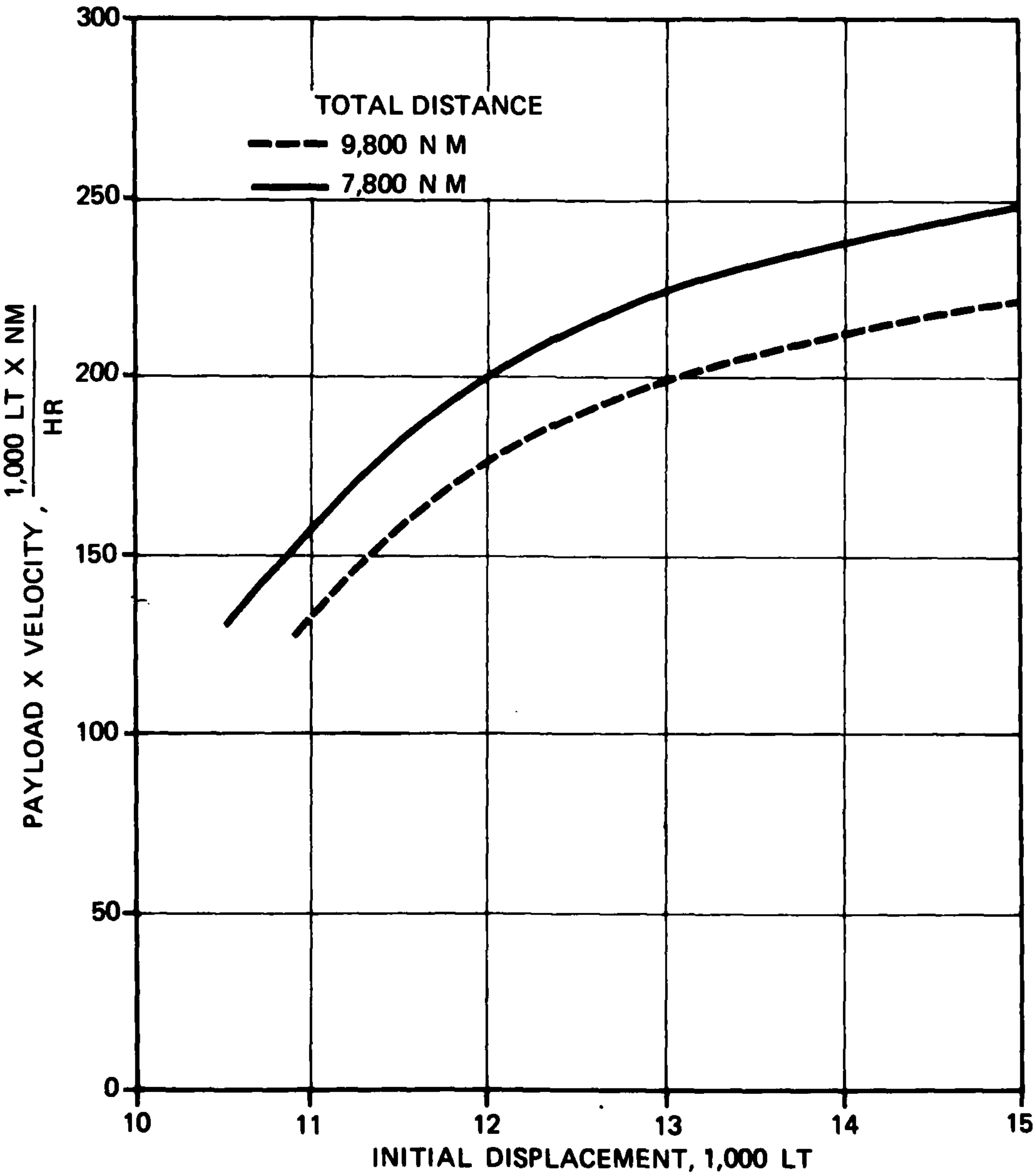


FIGURE 3–13

Results are based on the block-time or one round trip. The payload is carried on the outward leg, and the velocity is the average for the complete round trip. The example curves shown are for round trips of 7,800 and 9,800 nm. Corresponding curves can be produced for different ranges.

It can be seen that the product of payload and mean velocity continues to increase up to the maximum design displacement of 15,000 LT. This implies that if the purpose of the ship's mission is to transport as much cargo as possible at maximum speed, without regard to other factors, then the ship should always be loaded to 15,000 LT.

If, on the other hand, fuel economy is of prime importance, one would be guided by the relationships shown on Figure 3-14 which give plots of payload x velocity/fuel weight as a function of initial displacement for round trips of 7,800 nm and 9,800 nm, respectively. The curves show that the most efficient initial loading for the ship per unit weight of fuel is 12,750 LT for both cases.

3.3.2 Hullborne

The remaining three graphs show the ship's performance in the hullborne modes -- the first two curves are for the two turbine 54,000 hp case and the last two for the 14,000 hp diesel case.

Using the 15,000 LT example we can see from Figure 3-15 that the ship can carry 1,000 LT of payload 22,000 nm at an average speed of 25 knots in SS-3 (Figure 3-4) or 9,200 LT of payload for a distance of 1,000 nm at an average speed of 23 knots. The fuel required for these ranges (Figure 3-16) is 9,200 LT and 600 LT, respectively. All intermediate payload/range values for the six representative displacements can be found in a similar manner.

The final payload/range example is for the two diesel (14,000 hp) power levels. Again, referring to the 15,000 LT example, the MPS can carry 1,000 tons of payload for 42,500 nm or 9,400 LT of payload for 1,000 nm (Figure 2-3). The fuel requirements for these ranges are 8,500 LT and about 200 LT, respectively (Figure 3-17). Average speed for both cases is in the 14-15 knot range for SS-3.

3.4 MANEUVERABILITY

Preliminary calculations show that the MPS will have turning characteristics comparable or better than those of equivalent conventional ships.

3.4.1 High Speed Turning

Maneuvering can be effected by the use of rudders and/or variable pitch propellers. The propellers, located in the two sidewalls, are relatively widely spaced compared with those in conventional hulls, and therefore provide a significant amount of turning moment by means of differ-

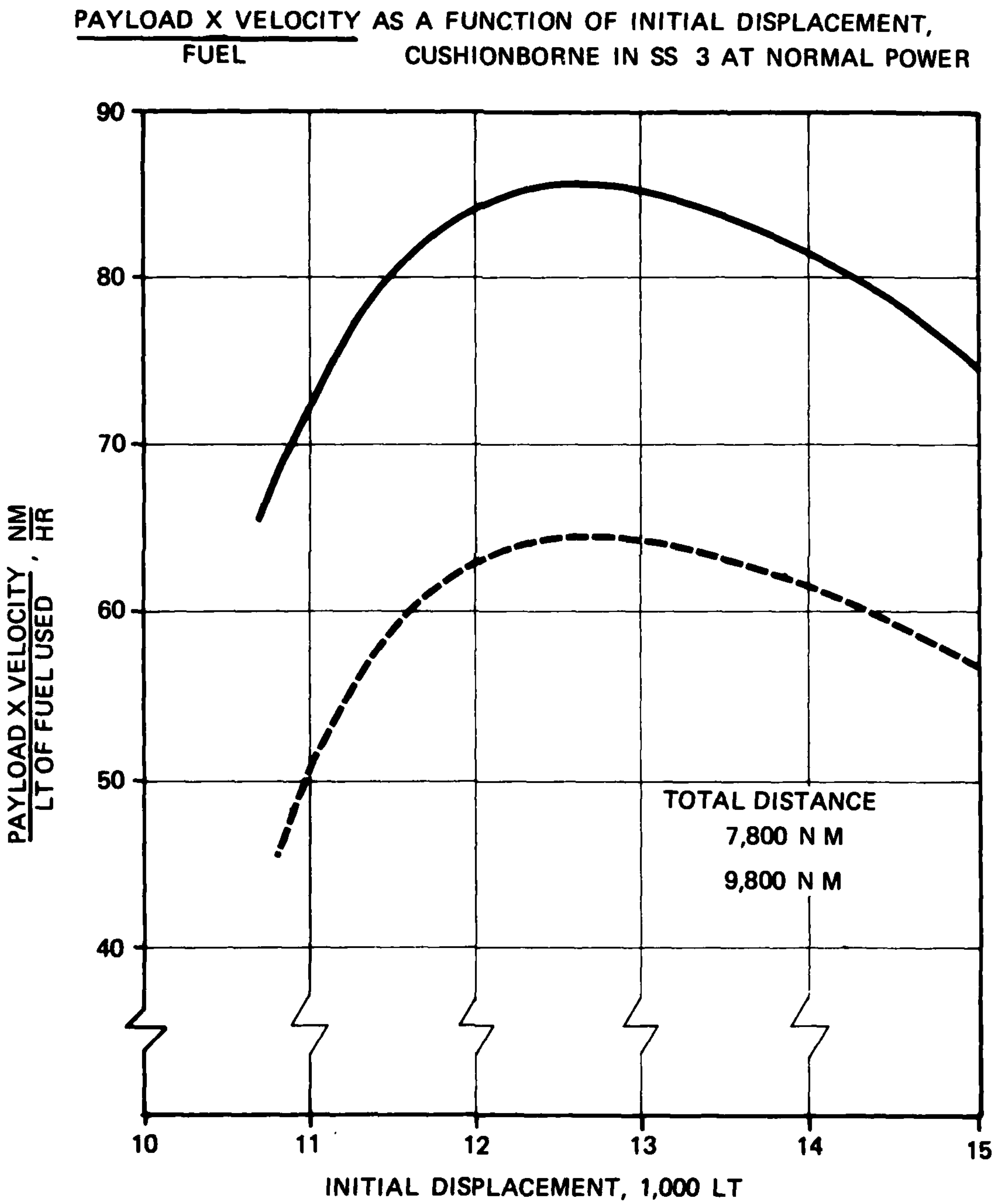

PAYLOAD X VELOCITY / FUEL AS A FUNCTION OF INITIAL DISPLACEMENT, CUSHIONBORNE IN SS 3 AT NORMAL POWER
90
80
70
60
50
40
PAYLOAD X VELOCITY / LT OF FUEL USED, NM / HR
TOTAL DISTANCE
7,800 N M
9,800 N M
10
11
12
13
14
15
INITIAL DISPLACEMENT, 1,000 LT

FIGURE 3–14

PAYLOAD VS RANGE AT TURBINE POWER (54,000 SHP), HULLBORNE IN SS 3

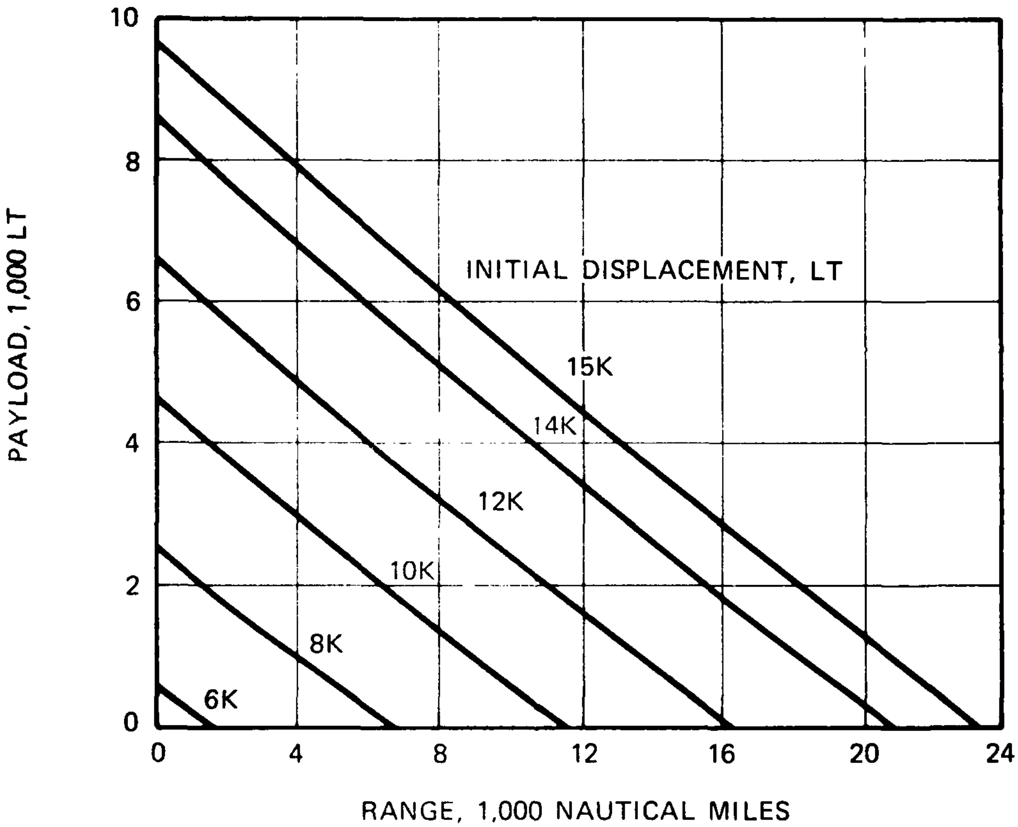


FIGURE 3–15

FUEL REQUIRED VS RANGE AT TURBINE POWER (54,000 SHP)
HULLBORNE IN SS 3

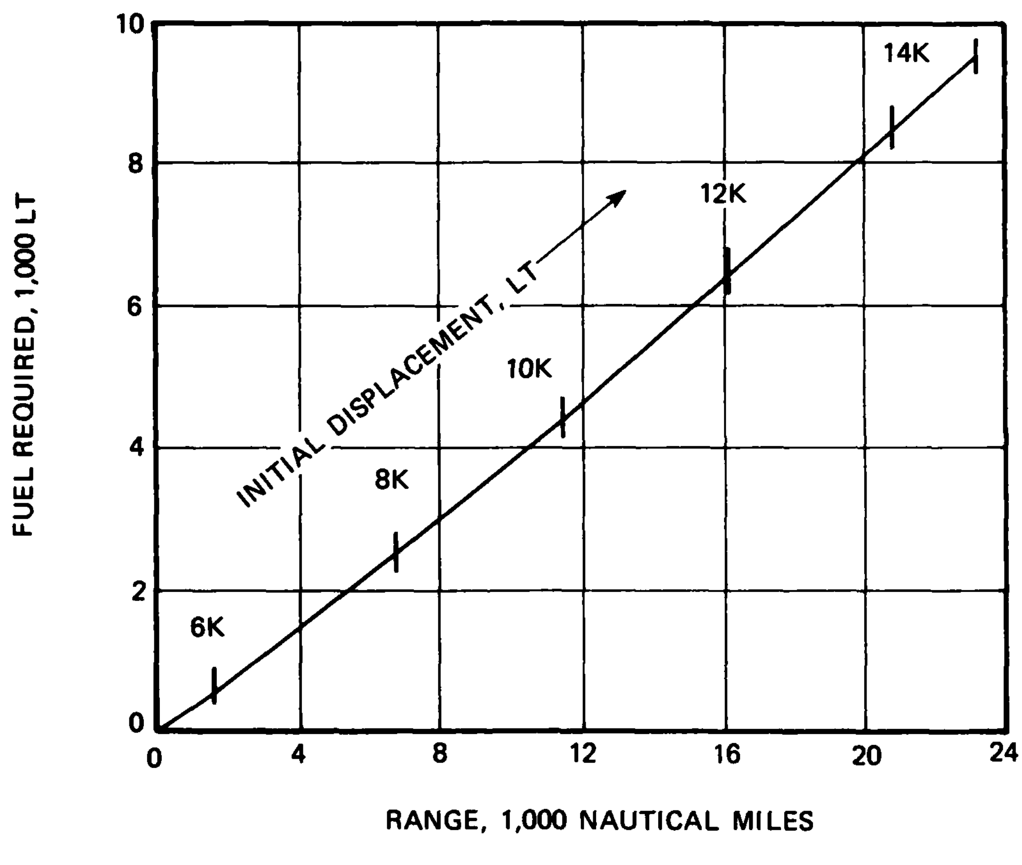


FIGURE 3–16

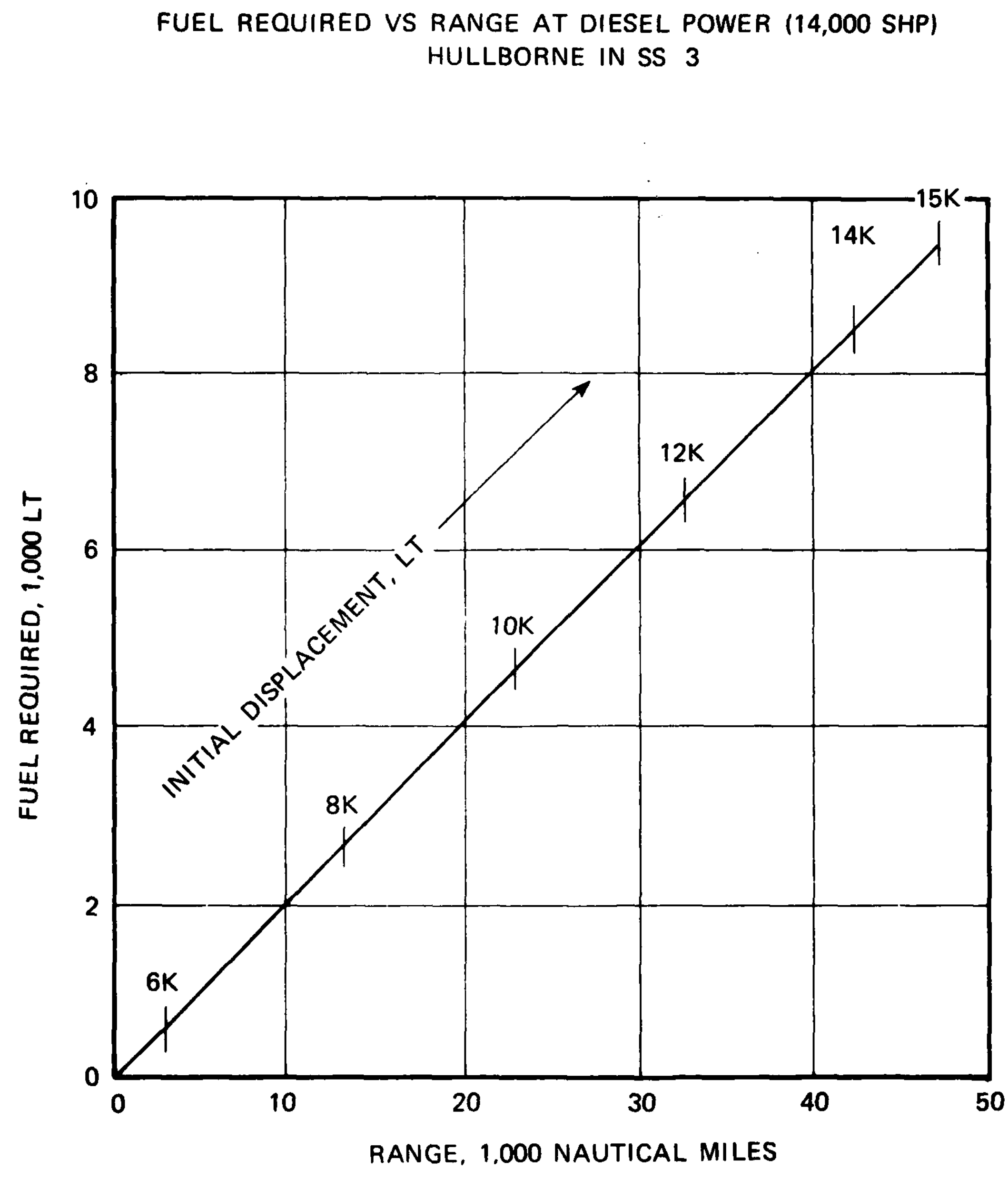

FUEL REQUIRED VS RANGE AT DIESEL POWER (14,000 SHP)
HULLBORNE IN SS 3
FUEL REQUIRED, 1,000 LT
RANGE, 1,000 NAUTICAL MILES
INITIAL DISPLACEMENT, LT
6K
8K
10K
12K
14K
15K
0
2
4
6
8
10
0
10
20
30
40
50

FIGURE 3–17

ential thrust in addition to that given by the rudders. Figure 3-18 shows calculated turning diameters for two rudder areas using rudders only for turning. The maximum turning diameter occurs at about 32 knots for either rudder area. For the 200 square feet rudders the maximum is approximately 12,000 feet and for 100 square feet, 20,500 feet. At other speeds the turning radius is smaller: for example at 20 knots, in the range of 6,000 - 8,000 feet diameter. Combining the rudders with differential thrust will further reduce the turning diameters. Considering the speed and size of the ship, the turning diameters are acceptable. It is assumed, therefore, that rudders in the area range of 100 - 200 square feet per side will be satisfactory for steering. The precise rudder size will be determined at the next stage of design.

3.4.2 Low Speed And Docking Maneuver

The ship is equipped with bow thrusters. These together with the differential and reversing capability of the propellers ensure that under normal circumstances the ship is self-steering and that tugs are not required.

3.5 STABILITY

The intact and damage stability investigation of the MPS is based on the requirements of NAVSEA DDS 079-1. Computations were performed using a computer program known as ARCC4. The program solves for values of roll angle, trim angle and draft so that the center of gravity is on the same vertical line as the center of buoyancy when the weight equals the buoyancy. A number of different loading conditions which cover the full range of payload/fuel combinations were considered.

3.5.1 Intact Stability

Calculations show that the intact stability far exceeds Navy requirements. The physical explanation for this is that the "catamaran" arrangement of the MPS produces considerable roll stiffness. Thus, for a 100 knot beam wind, roll angle is in the range of 1 - 2 degrees. For the worst loading case considered, the range of positive stability is 56 degrees. It is considered that the range of stability combined with the high roll stiffness is sufficient to ensure a safe ship in any envisioned operational sea state.

3.5.2 Stability In Damaged Condition

Damage stability was examined for the two conditions of longitudinal damage specified in DDS 079-1 Part III, namely, a shell opening equal in length to 15 percent of the design water line length with 50 percent penetration, and a shell opening equal to 50 percent of the design waterline length with transverse extent to the first inboard longitudinal bulkhead (no less than 10 percent of the beam). The two conditions were considered in conjunction with various payload/fuel combinations. For the vast majority of cases considered, the ship satisfied

ESTIMATED TURNING DIAMETER, 10,000 LT DISPLACEMENT, CUSHIONBORNE IN SS 3

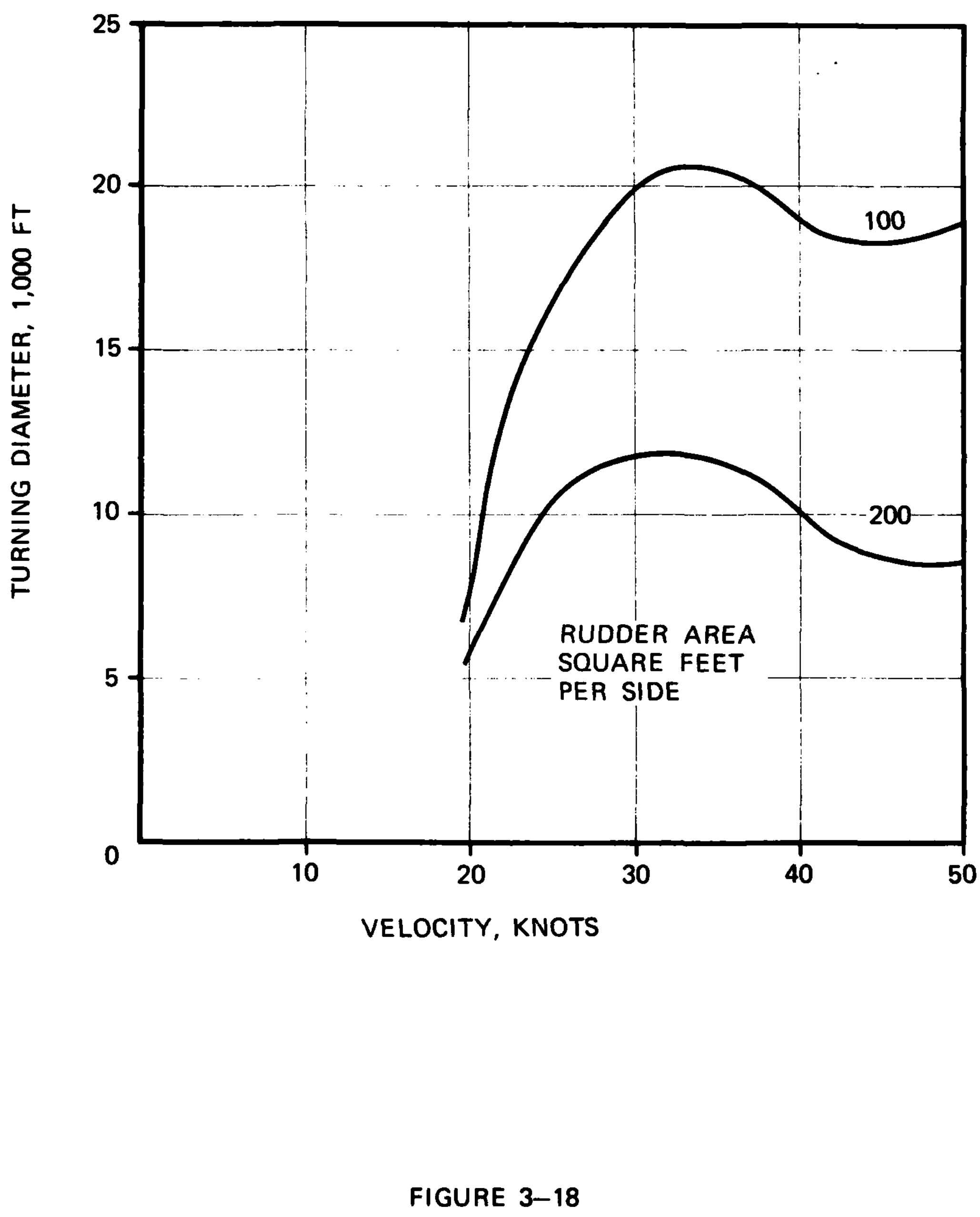


FIGURE 3–18

the NAVSEA criteria. The margin line in the forward and after sections of the MPS will be sufficient to result in a satisfactory damage stability for all specified cases.

4. SUBSYSTEM DESCRIPTIONS

4.1 HULL STRUCTURE

4.1.1 Structural Arrangement

The hull consists of a box-like centerbody with integral catamaran-like rigid sidehulls. Hull panels are longitudinally stiffened and supported by transverse beams, arranged as an "egg crate", Figure 4-1. Sidehulls are faired for proper hydrodynamic performance, and at fore and aft locations are compatible with the seals arrangement. The sidehulls are extended forward at the bow to absorb transverse loads in the seal bag and thus to reduce stresses in the seal seams.

The fourth deck is located near the neutral axis and contributes little to the bending resistance of the hull. Scantlings for this deck are determined only by local cargo loads. For this reason, portions of the fourth deck are made removable to save weight when deck space is not needed. An additional removable deck is provided between the second and fourth decks. The removable decks will be used when an airborne division is loaded or when units of an armored division are carried.

The bow structure angle of 30 degrees was chosen to minimize hullborne slamming loads. This ramp structure is provided with approximately 200 square feet of vent openings to provide a pressure relief system for the bow seal bag. Figures 4-1, 4-2 and 4-3 show the ship's structural arrangement and dimensions. Figure 4-4 shows removable cargo deck details.

4.1.2 Operational Envelopes

The MPS is designed to operate in the open ocean (the North Atlantic) for twenty years (67,000 operational hours) within the performance envelope provided in Table 4-1. Approximately 2/3 of the operational time will be cushionborne and 1/3 hullborne.

The ship's loads criteria, presented in Figure 4-5 were formulated to satisfy these operational conditions. These preliminary loads are largely based on analyses of high L/B SES model data, supplemented by applicable information derived from the 3KSES program and from manned at-sea SES test results.

As in the case of the 3KSES, the MPS loads are based on the 0.999 probability of survival. This represents, on the average, one chance in a thousand, that the ship would suffer major structural damage that will cause termination of the mission.

The safety factors specified in notes to Figure 4-5 are based on risk analyses performed under the 3KSES program and account for uncertainties related to loads and fabrication variables. Conservatism is provided by the material allowables, which are based on the minimum rather than the average material properties which are 10-15 percent higher. Figure 4-6 illustrates the data analysis process that provided the basis for the MPS structural loads and safety factors.

TYPICAL STRUCTURAL ARRANGEMENT

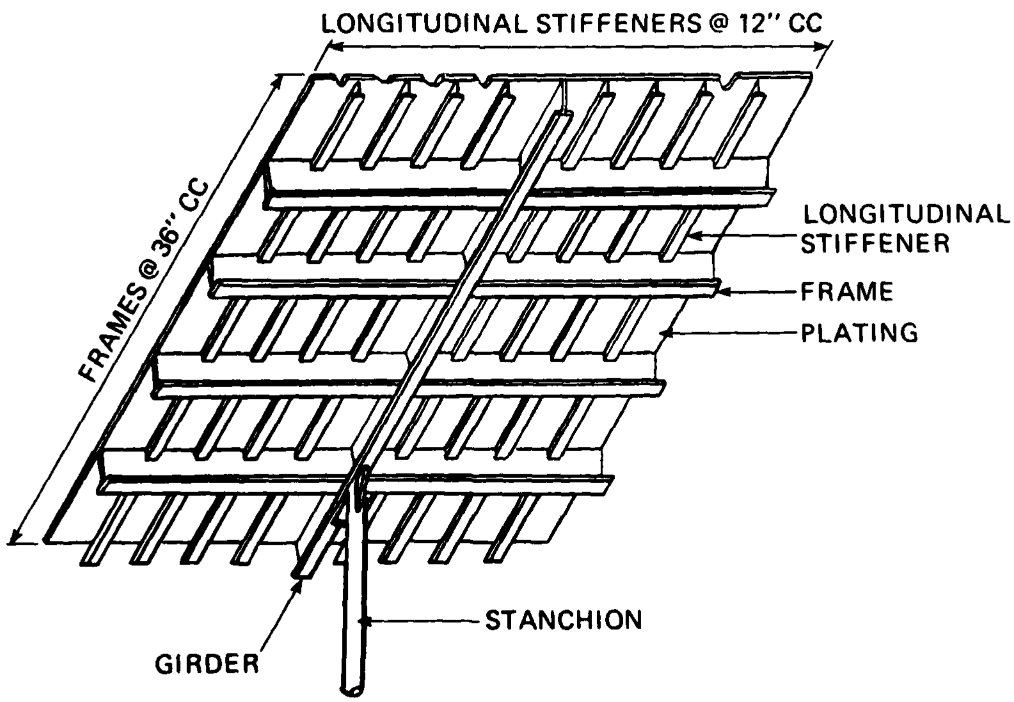
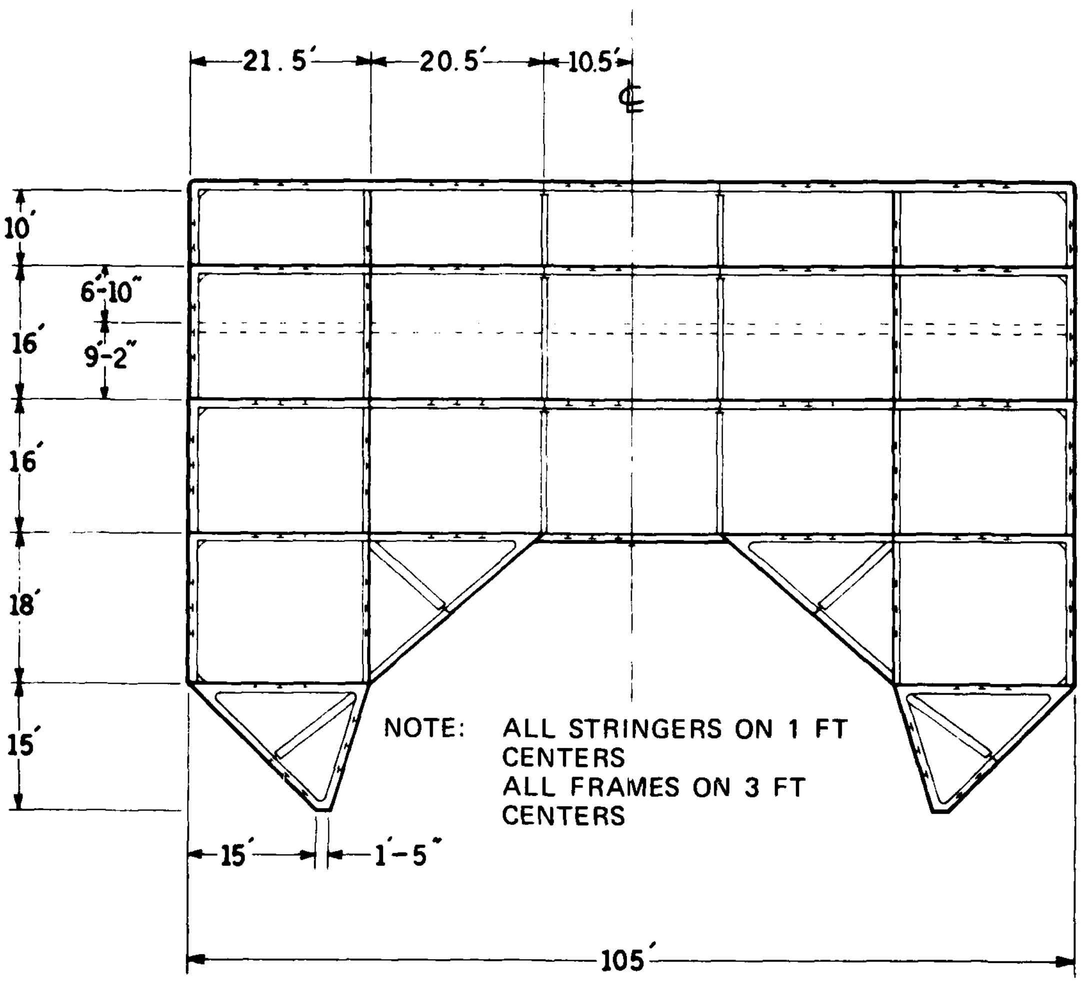


FIGURE 4–1

TYPICAL STRUCTURAL SECTION



NOTE: ALL STRINGERS ON 1 FT CENTERS
ALL FRAMES ON 3 FT CENTERS

FIGURE 4–2

TYPICAL STRUCTURAL BULKHEAD

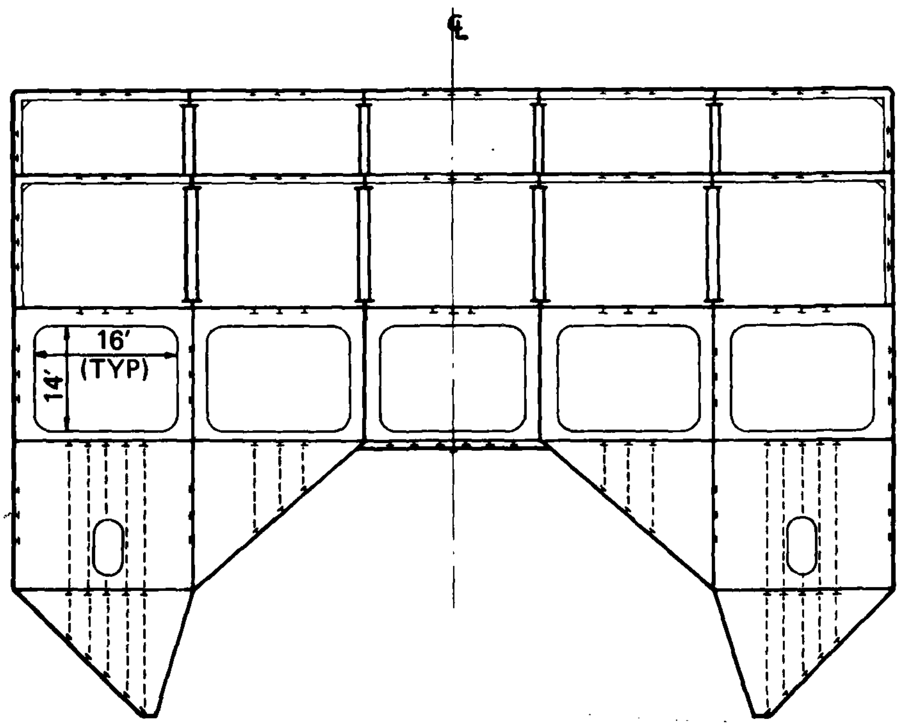
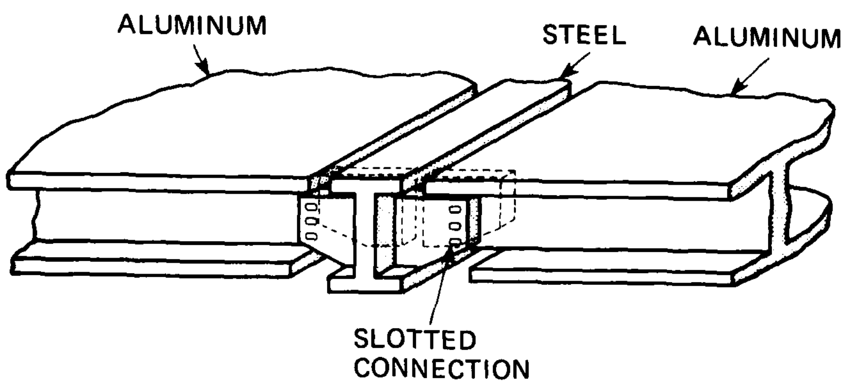


FIGURE 4–3

REMOVABLE 3rd DECK



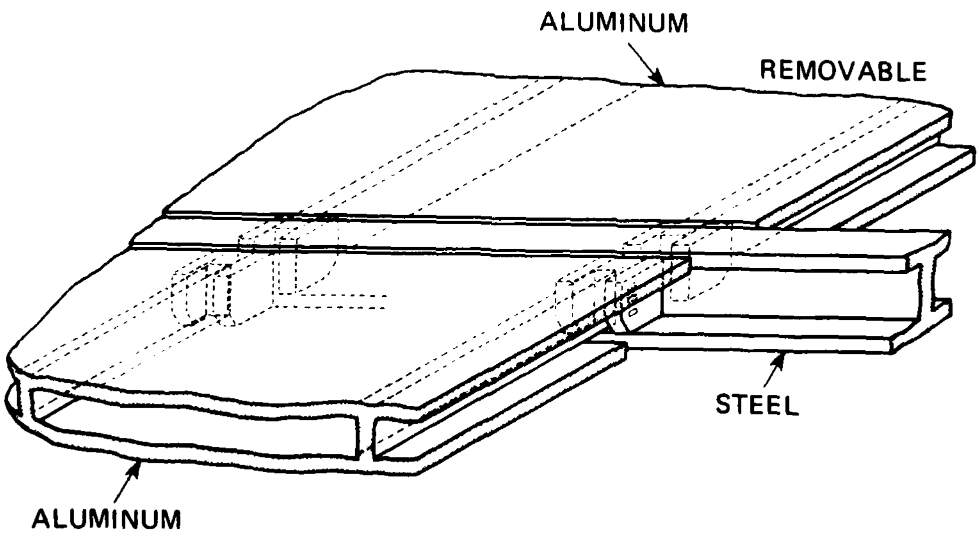


FIGURE 4–4

SHIP'S LOADS CRITERIA

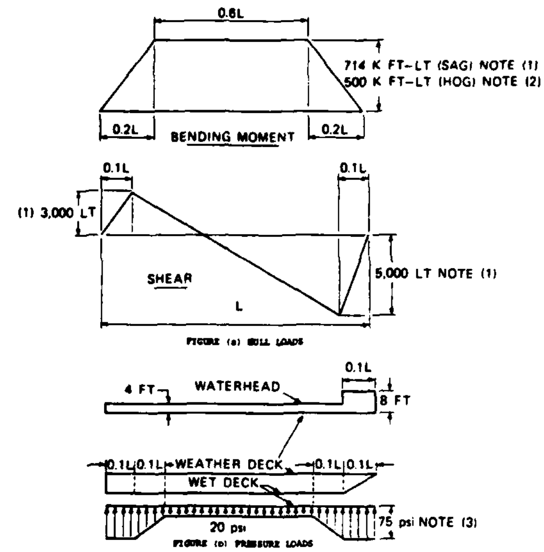


FIGURE (a) HULL LOADS

FIGURE (b) PRESSURE LOADS

(1) Hullborne shear and bending moment are based on L/B = 5 SES model test data (one–in–a–thousand maximum load)

(2) Cushionborne bending moment is based on 3KSES test data (one–in–a–thousand maximum load)

(3) Slamming pressures are based on 3KSES model and XR–1D test data

Use 70% of the Figure 3(b) slamming pressures for wetted area widths in 3 to 5 ft range

For more than 4 ft, reduce the Figure 3(b) pressures by 50%.

<u>Design Criteria Summary</u>

1. ADDITIONAL LOADS

1.1 Live Loads 150 psf 3rd deck
300 psf 1st and 2nd decks and machinery platform
500 psf 4th and 5th (wet) decks

1.2 Maximum Cushion Pressure Load 3 x 700 = 2,100 psf

1.3 Wave Slap Loads 500 psf from 1st to wet deck

500–2,100 psf (trapezoidal distribution) from wet deck to keel

2 SAFETY FACTORS (SF)

		YIELD	ULTIMATE
2.1	Live Loads plus Hullborne Loads	1.2	1.5
2.2	Live Loads plus Cushionborne Loads plus Maximum Cushion Pressure Load	1.2	1.5
2.3	Wave Slap Loads	1.2	1.5
2.4	Slamming Loads	1.0	1.2

FIGURE 4–5

HULL LOADS – ILLUSTRATIVE EXAMPLE

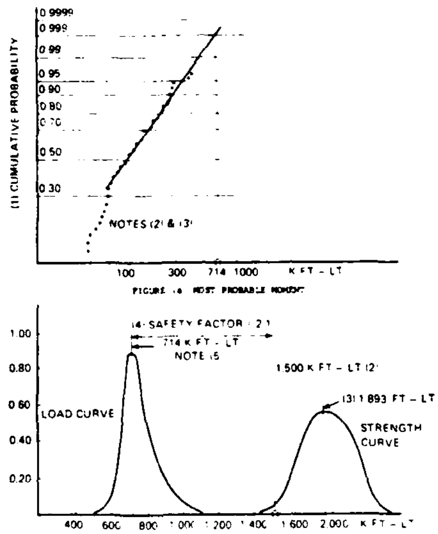


FIGURE 4–6(a)

(1) Cumulative probability is established by load events observed during the towing tank tests

(2) Experimental measurements are scaled to MPS

(3) All measurements were taken at the forward 1/4 point. For midship bending moment the measured values were increased 43%. This increase was determined by comparing mid–ship and 1/4 point measurements from the 1:30 scale 3KSES model

(4) The most probable load is based on 1,000 slamming encounters

FIGURE 4–6(b)

(5) Most probable bending moment from Figure 4–5(a)

(6) Computer hull strength (minimum strength)

(7) Average hull strength

(8) Available safety factor 1,500,000/714,000 = 2.1*

* Safety factor exceeds the 1.5 value specified by the criteria. This indicates that hull design is conservative and structural weight (or cost) may be reduced

FIGURE 4–6

TABLE 4-i
MPS PERFORMANCE ENVELOPE

MODE	SEA STATE	V_K (Kt)	DISPLACEMENT	HEADING
I Cushionborne	0	60 Kt	MOD	Any
II Cushionborne	6	30 Kt*	ALL	Any
III Hullborne	3	15 Kt	MOD	Any
IV** Hullborne	7-9	Steerage Speed (3-5)	ALL	Any

MOD = Mean Operating Displacement

*Forward velocity should be adjusted to obtain same loads as hullborne conditions IV

**Partial cushion operation may be used to reduce loads

4.1.3 Hull Materials

Candidate materials for the hull structure are summarized in Table 4-ii. With the exception of HTS and X-80-W steels, rolled shapes are unavailable and frames and stiffeners must be fabricated from plate material. Weight and cost comparisons for these materials are tabulated below.

HULL MATERIALS - WEIGHT & COST COMPARISON

	HTS	HY80	HY100	HY130	AL5456	HSLA STEEL REPUBLIC X-80-W
Hull Weight (LT)	5360	4100	3920	3850	2500	4200
Cost*	1.0	1.73	1.65	2.16	2.13	0.60

*Cost relative to HTS hull structure

The newly developed commercial high strength alloy (HSLA) steel represents the most economically attractive material. Since it exhibits marginal ductility, it represents a higher risk than the other candidate materials. Recently, General Motors Research laboratories developed a simple heat treatment for HSLA steel which greatly improved its ductility without sacrificing the strength. This and other HSLA steels now being tested to determine their suitability for marine applications. Aluminum provides the lightest structure but the material cost is high, fabrication relatively difficult, the structure requires passive protection from fire and is more prone to fatigue cracking. HTS steel is economical and used extensively in ship construction. However, the HTS steel hull is significantly heavier than any of the high yield (HY) steel hulls and is ruled out as a candidate material. HY130 steel is marginally lighter than either HY80 or HY100 steels but costs considerably more and is more difficult to weld. HY100 steel represents the best material compromise for the MPS, with HY80 steel being a close second.

CANDIDATE BASE PLATE MATERIALS

MATERIAL	HTS	REPUBLIC X-80-W*	HY-80	HY-100	HY-130	5456 AL
Chemistry (%) Typical	C-0.18 Ni-0.20 CR-0.10 Mn-1.00 Cu-0.30	C-0.22 Mn-1.40 Si-0.25 V-0.14 Cb-0.015	C-0.16 Ni-2.50 Cr-1.40 Mo-0.40	C-0.18 Ni-2.75 Cr-1.40 Mo-0.40	C-0.12 Ni-5.00 Cr-0.60 Mo-0.50 V-0.05	Mg-4.7/5.5 Mn-0.5/1.0 Cr-0.05/0.20 Cu-0.10
Available Forms **	Wrought		Wrought and cast	Wrought and cast	Wrought and cast	Extrusion
Thickness Range, (Inches)	1/4 to 15	3/16 to 3/4	3/16 to 8	3/16 to 5	3/16 to 6	3/16 to 2
Material Base Price ($)	0.35/1b	0.25/1b	0/79/1b	0.75/1b	1.05/1b	1.60/1b
Electrode Cost	0.65/1b	2.60/1b	2.60/1b	2.87/1b	8.20/1b	--
Lead Time (Months)	3	3	3	3	3	6
<u>Mechanical Properties</u>						
Yield Strength (ksi)	50 min	80 min	80 - 100	100 - 120	130 - 150	26
Tensile Strength (ksi)	92 max	95 min	---	---	---	40
Elongation (%)	---	12 min	19 min	17 min	11 min	20 min
CVN (ft - lbs)	---	16-39 @ $0^{o}F$	50 @ $-120^{o}F$	50 @ $-120^{o}F$	60 @ $0^{o}F$	---
Specification	MIL-S-16113	Republic Steel	MIL-S-16216	MIL-S-16216	MIL-S-24371	QQ-A-00240/19

*Manufacturers Data - No commercial or military specification requirement.

**All available in plate form

TABLE 4-ii

Aluminum 5456 is contemplated for the superstructure and for removable decks, ramps and doors. High strength fire retardant fiberglass will be used in the deckhouse structure, wherever it is more economical than aluminum.

4.1.4 Fabrication Methods

The basic stiffening arrangement of 36 inch frame and 12 inch longitudinal stiffener spacing is maintained throughout the ship. Most of the structure consists of flat, two dimensional elements. Complex surfaces represent a small percentage of the hull structure and are largely limited to forward extremities.

These characteristics suggest a modular type construction, where the hull is assembled from small subassemblies fabricated in a sheltered and controlled environment. It is envisioned that all stiffened panels will be fabricated in a panel shop using automated welding. Since the major portion of the weld footage is contained in stiffened panels, automated panel welding represents the greatest cost saving. Table 4-iii summarizes mechanized processes suitable for this ship's construction. Based on current industrial capability and experience, the first three processes; i.e., gas metal, submerged and flux-cored arc welding, represent the immediate options for tee and butt welding.

TABLE 4-iii
PANEL SHOP FABRICATION/MECHANIZED WELDING

	HTS	REPUBLIC X-80-W	HY-80	HY-100	HY-130
AVAILABLE MECHANIZED PROCESSES					
GAS METAL ARC WELDING	(1)	(1)	(1)	(1)	(1)
SUBMERGED ARC WELDING*	(1)	(1)	(1)	(1)	(2)
FLUX CORED ARC WELDING	(1)	(2)	(2)	(2)	(3)
ALTERNATIVE PROCESSES					
LASER BEAM WELDING	(3)	(3)	(3)	(3)	(2)
ELECTRON BEAM WELDING**	(2)	(2)	(2)	(2)	(2)
PLASMA ARC WELDING	(2)	(2)	(1)	(1)	(1)
RESISTANCE/FORGE WELDING	(3)	(3)	(3)	(3)	(3)

(1) Existing production technology

(2) Base technology available/requires additional development

(3) Requires extensive development

*Flat or horizontal position welding

**Requires vacuum chamber

Electron beam (EB) welding appears a potential candidate for frame and stiffeners "T" fabrication and may be extended to stiffened panels. The main disadvantage of this process is that it requires a vacuum chamber which limits the sizes of subassemblies.

Laser welding is a relatively new technology as yet untested by the shipbuilding industry. It offers advantages of high speed (50 inches per minute), and a capability of automatically welding the transverse frames to the longitudinally stiffened panel. This last operation will be slow and costly if conventional manual welding is used. Industrial EB or laser welding equipment for mass producing fabricated "T" shapes are available but have not been integrated into an automated commercial facility. For the present, EB and laser welding are considered as desirable, but not required, fabrication procedures.

Table 4-iv lists existing automated panel welding facilities that could be used in MPS construction. Stiffened panel subassemblies will be joined into modules by gas metal, submerged and flux-cored arc welding as appropriate. These procedures proved to be more economical than conventional manual shielded metal arc (stick) welding, resulting in up to 50 percent cost saving. Similar welding techniques will be used for final assembly.

TABLE 4-iv
LIST OF KNOWN PANEL LINE FACILITIES

1. Avondale Shipyard, New Orleans, Louisiana
2. Bath Iron Works, Bath, Maine
3. Bethlehem Steel Shipyard, Sparrows Point, Maryland
4. Dravo Fabrication, Pittsburgh, Pennsylvania
5. Equitable Shipyard, Madisonville, Louisiana
6. General Dynamics, Quincy, Massachusetts
7. Halter Marine, Calumet, Louisiana
8. Jeff Boat, Jeffersonville, Indiana
9. Levingston Shipyard, Orange, Texas
10. Litton Ingalls Shipyard, Pascagoula, Mississippi
11. National Steel Shipbuilding and Drydock, San Diego, California
12. Newport News Shipbuilding, Newport News, Virginia
13. Sun Shipbuilding, Chester, Pennsylvania
14. Todd Shipyard, Los Angeles, California

4.1.5 Structural Weight Breakdown

Detailed SWBS Group 100 breakdown and percentages of total structure are presented in Table 4-v.

TABLE 4-v
WEIGHT OF STRUCTURE SWBS GROUP 100
INCLUDING MILL TOLERANCES AND WELD MATERIAL

WEIGHT GROUP	DESCRIPTION	WEIGHT LT	% TOTAL STRUCTURE
*110	Shell & Support Structure	1,750.7	44.7
*120	Hull Structure Transverse Bulkheads	108.3	2.8
*130	Hull Decks	1,536.2	39.2
*140	Hull Machinery Flats & Platform	193.4	4.9
150	Deck House Structure (Aluminum)	95.5	2.4
*160	Special Structures (HY-100 Steel)	62.0	
	(Aluminum)	62.2	3.2
170	Masts, King Post & Service Platform	9.0	
	(Aluminum)		0.2
180	Foundations (Aluminum)	99.7	2.6
100	Hull Structure, Total	3,917.0	100.0

*Constructed from HY-100 Steel

4.1.6 Structural Risk Assessment

Risks associated with any ship structure, including the MPS, can be divided into the following categories:

a. Inadequate hull strength.

b. High fabrication costs.

c. High maintenance costs.

Hull strength is dependent on an accurate assessment of loads, materials and fabrication variables. MPS loads are based on extensive towing tank model tests. These models differ from the MPS configuration in regards to L_c/B_c ratio and sidehull shapes. Current indications are that the loads derived from these tests are conservative and that the MPS configuration will experience lower slamming loads. Experimental confirmation of this observation is needed to further reduce structural weight. The risk related to structural strength is considered moderate, and will be reduced to negligible as more loads data and analyses related specifically to MPS are made available.

There is a modest risk in the materials and fabrication cost areas due mainly to limited shipyard experience with thin, high strength steel construction; however, assembly of a structure representative of the MPS hull would provide adequate experience to eliminate this risk.

Risks related to structural maintenance are considerably lower than those associated with aluminum ship maintenance i.e., PHM, AALC etc., and comparable to those related to high strength steel submarine hull construction. Actually, it is anticipated that thinner scantlings (as compared to a submarine pressure hull) will provide better toughness and better fatigue life and therefore a substantial reduction in structural repairs.

4.2 SEAL STRUCTURE

4.2.1 Seal Description

The bow and stern seals, Figures 4-7 and 4-8 represent adaptations of the "bag and finger" type seals successfully used on many ACV's and SES's. The major factors that influenced the decision to use "bag and finger" type seals for the MPS were: availability of a wealth of data on loads; performance of materials; and fabrication methods for these seals. Further considerations were the relative simplicity and low weight of tensioned fabric seals and their demonstrated ability to perform well in the dynamic environment.

The seals are designed to satisfy the preliminary requirements presented in Table 4-vi.

Material characteristics are summarized in Table 4-vii. These materials provide a combination of structural and chemical properties best suited to meet requirements dictated by the ship operational environment.

The main structural features of the seals are summarized as follows:

a. Bow Seal - The upper portion of the seal consists of a two dimensional inflated bag structure that extends straight across the ship and is contained by the sidehulls. A three lobe arrangement was chosen to maintain bag material stress levels under 5100 pounds per linear inch (pli). The 5100 pli fabric strength represents the current manufacturing state-of-the-art. The bag structure is assembled from a number of elastomer coated panels bonded together at the seams. The spacing and number of seams are dictated by the maximum width of presently available commercial fabric that ranges from approximately 4.5 to 20 feet, depending on the method for applying elastomer coating. The 4.5 foot width fabrics are readily available and less costly but will result in more seams and higher overall construction costs. It is intended to use only flexible bonded seams since they provide the best strength and fatigue performance. Typical seam and hard structure connection details are shown in Figure 4-9. Figures 4-10 and 4-11 provide data on strength of seams and coated fabrics. Seam strength is one of the critical parameters in seal design. The gap between the lower bag loop and the water is filled by seal fingers. Figure 4-12 shows a typical finger configuration. All fingers are identically constructed. Mechanical fasteners at the bag and hard structure connections allow easy replacement.

BOW SEAL CONFIGURATION

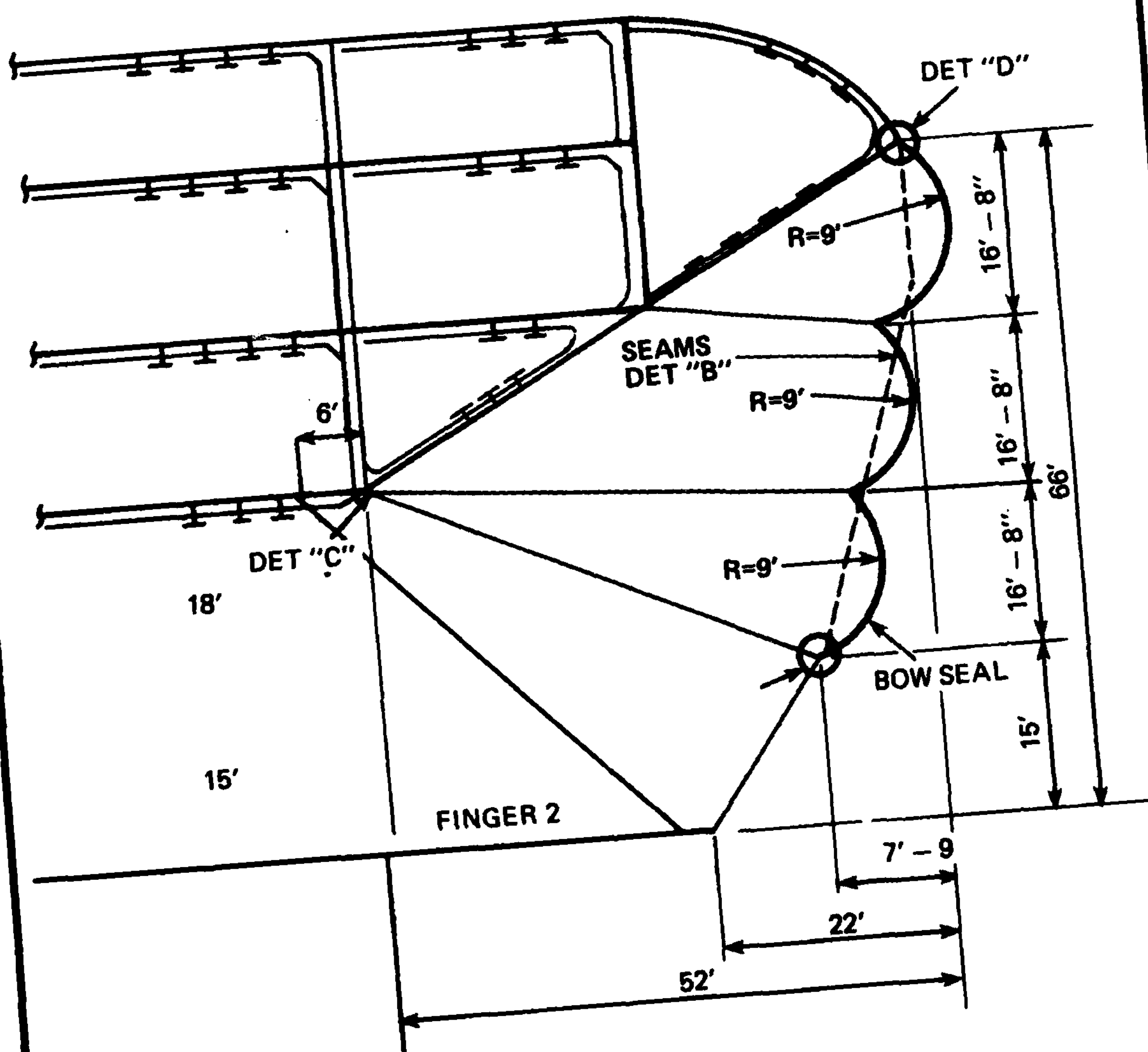


FIGURE 4–7

STERN SEAL CONFIGURATION

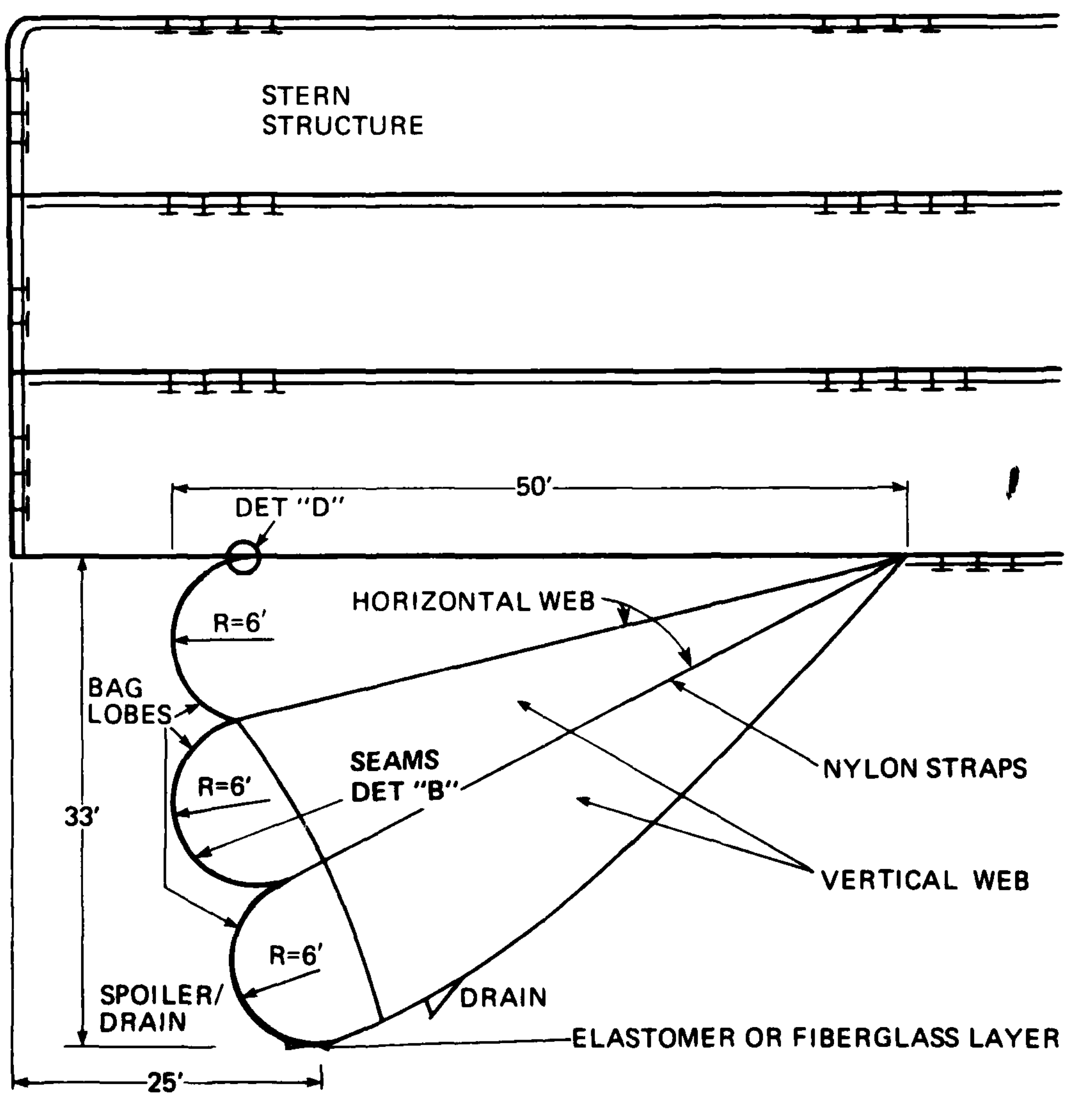


FIGURE 4–8

SUMMARY OF SEAL STRUCTURAL DESIGN CRITERIA

Critical Combination Bag and Cushion Pressure

Bag Pressure (P_b)	= 2100 psf	Maximum bag load	= 2000 pli
Cushion Pressure (P_c)	= 2100 psf	Maximum finger load	= 650 pli

Drag Loadings

Immersion (ft)	15.0
Speed (kt)	30.0

Water Carry

With P_b = 770 psf, the bag (while filled with water to the bag inner hinge level) is lifted from the water to cushionborne position.

Ship is hullborne. Mass of water in bag accelerated at 3.5g at bow and 2.0g at stern.

Bag and Finger Re-inflation

With P_b	= 1500 psf
Bag and finger material acceleration P_c	= 50 g's

Water Scooping

With fingers fully immersed and craft backing up at low speeds with initial acceleration = 1.0g.

Safety Factor

Factor of safety of 2.5 (2.0 for material strength plus 0.5 for material degradation).

Seal Life

Bag shall be designed for a minimum service life of 5000 operational hours. Fingers shall have a minimum service life of 1333 operational hours with a maximum of 24 inches of tip wear.

TABLE 4-vi

BOW AND STERN SEAL DETAILS

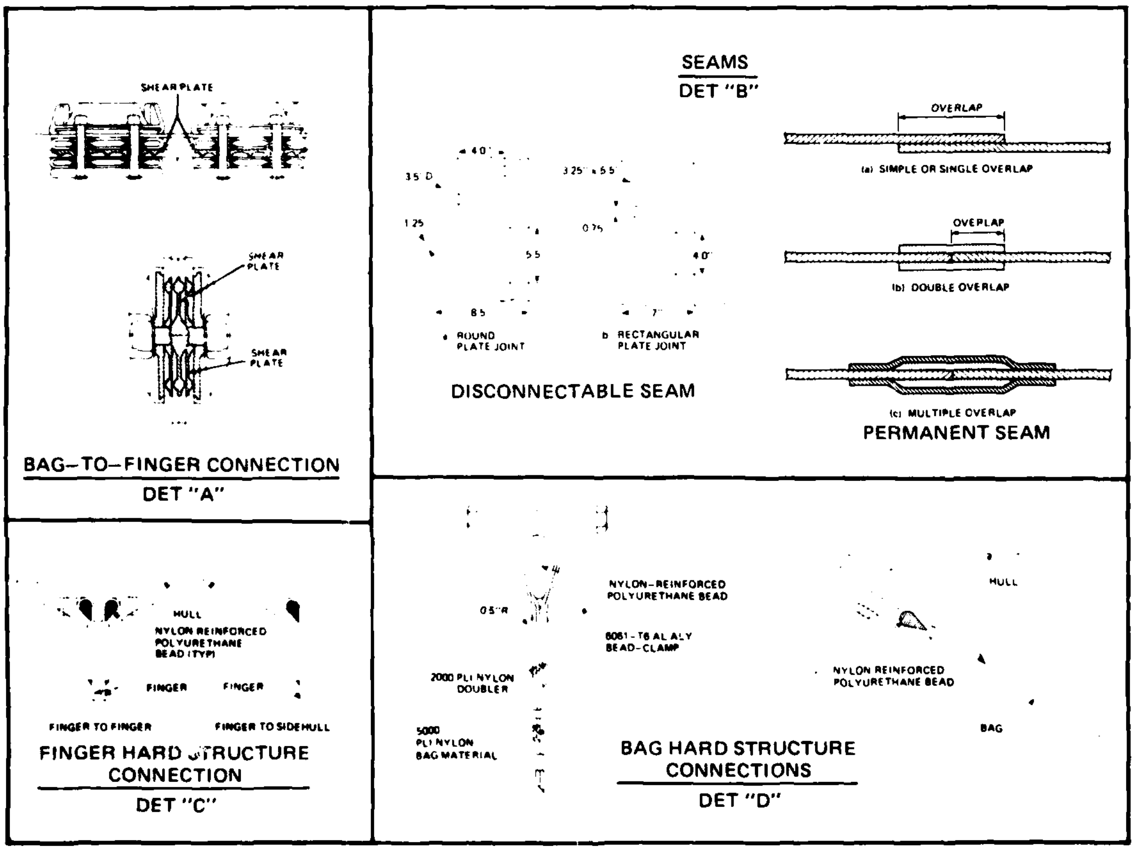


FIGURE 4–9

BONDED SEAM STRENGTH CAPABILITIES

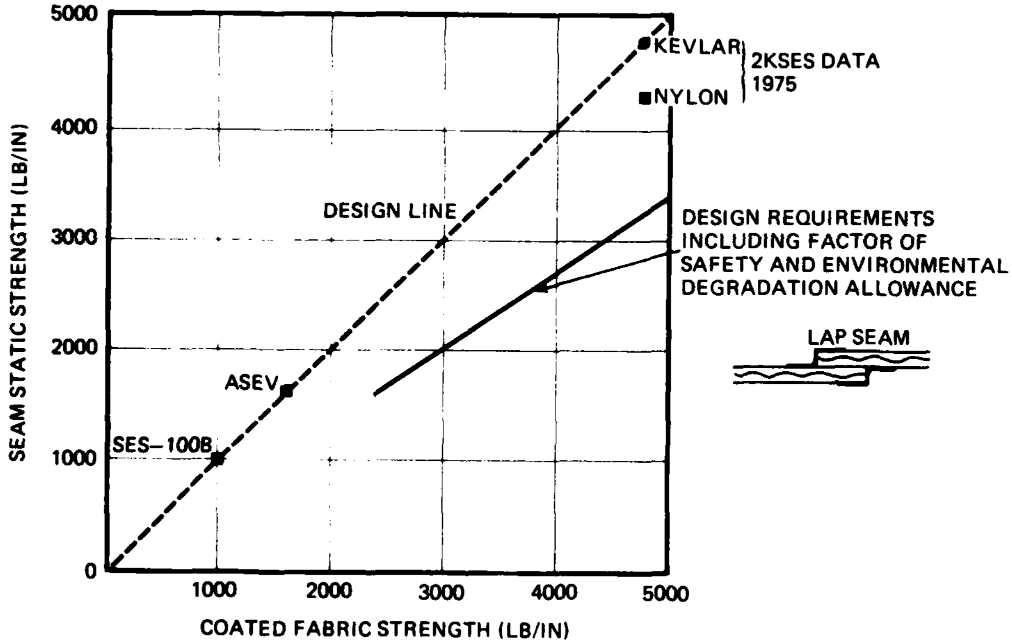


FIGURE 4–10

LOAD ELONGATION CURVE FOR RUBBER COATED FABRIC
PREPARED WITH BAC 214 ADHESIVE AND UNCOATED FABRIC

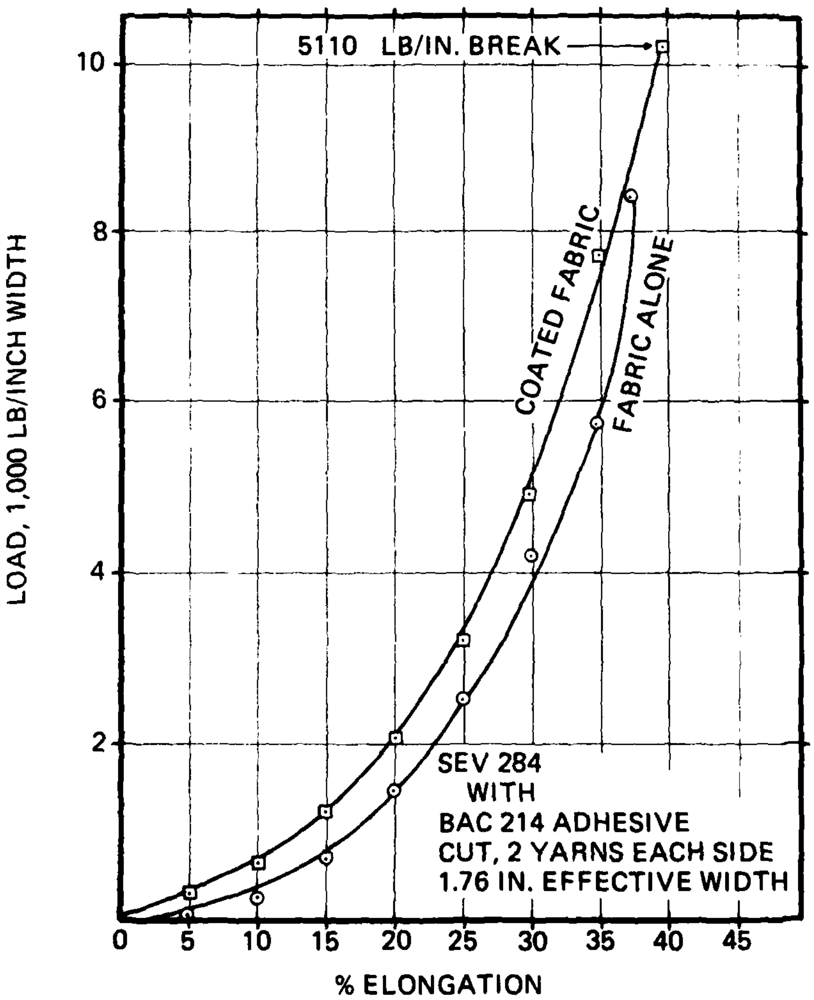
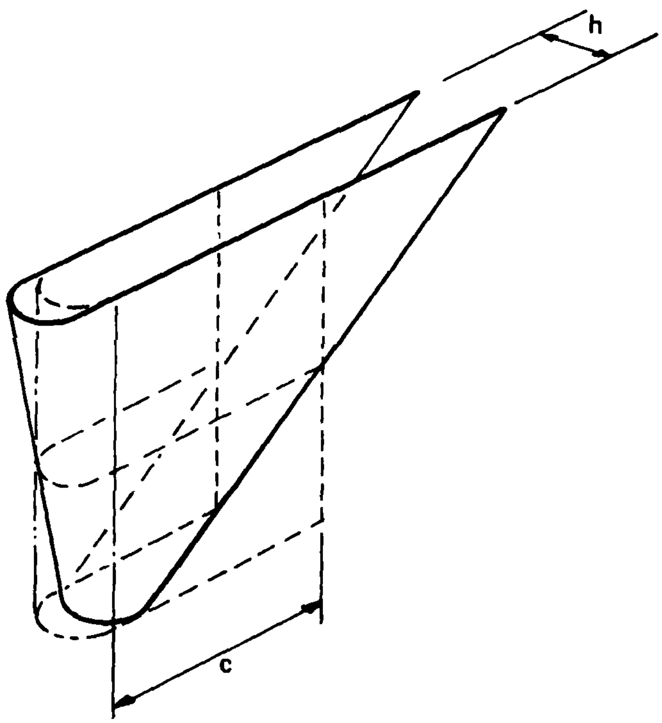


FIGURE 4–11

TYPICAL BOW SEAL FINGER (SCHEMATIC)



c = EQUIVALENT WIDTH OF FLAT FOR PRISMATIC BEAM

h = FINGER DIAMETER

FIGURE 4–12

TABLE 4-vii
CHARACTERISTICS OF BAG AND FINGER MATERIALS

CHARACTERISTIC	BAG	FINGERS
Fabric Type	Nylon basket weave	Nylon 3 x 4 basket
Fabric Weight	50 oz/yd^2	53.5 oz/yd^2
Coating	Neoprene base rubber	Isoprene/butadiene base rubber
Tie-Coat	Neoprene base Tie coat adhesive	Neoprene base Tie cost adhesive
Coated Material Weight	180 oz/yd^2	170 oz/yd^2
Tensile Strength		
Warp	5000 pli (per linear inch)	2520 pli
Fill	1500 pli	3470 pli
Tear Strength	500 lb (min)	1200 lb
Elongation		
Warp	24%	24%
Fill	24%	22%

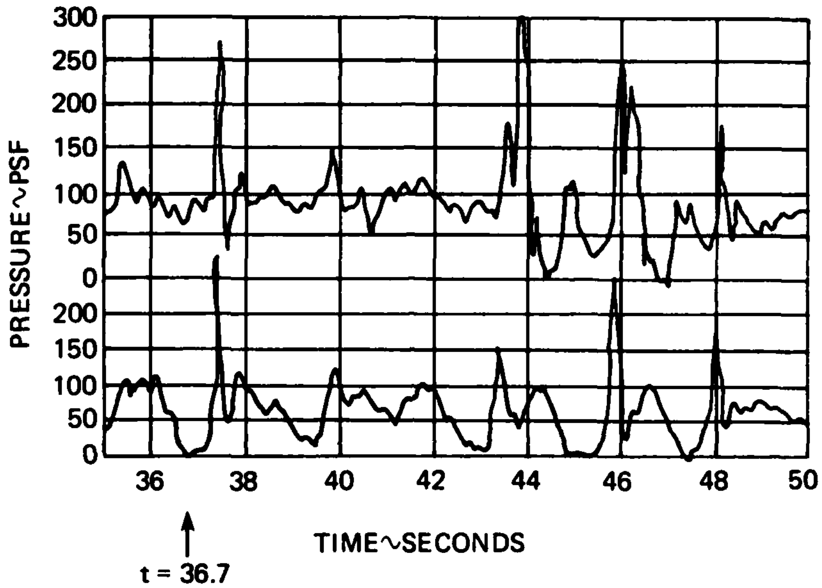
NOTE: Minimum required finger material strength is 2400 pli in warp and in fill. The above finger material exceeds this requirement, and was selected because it was test qualified under the 2KSES development program.

b. Stern Seal - The stern seal consists of a simple multi-lobe bag similar to the one successfully tested on several SES testcraft. The hard structure connections and bag seams are constructed in a manner similar to the bow seal. Whenever possible the connections for the stern seal are made interchangeable with those for the bow seal.

4.2.2 Seal Loads

The seal is designed to withstand 3 times the pressure cushion = 2100 psf pressure in a fully deployed condition. This condition corresponds to the overpressure loads case and represents the maximum threshold load at which the pressure relief system is activated. On three occasions the cushion pressure bag loads were observed during SES-100B tests, Figure 4-13. Other loads shown on Table 4-vi are assumed to be less critical. This assumption is supported by 100-ton SES experience and will be verified by further tests and analysis.

CUSHION PRESSURE IN LARGE WAVES[1]



NOTE: (1) IN THIS CONDITION THE SHIP HAS CRESTED A WAVE AND A THIRD OF ITS LENGTH IS CLEAR OF THE WATER. THE CUSHION PRESSURE PLOT SHOWS THIS PRESSURE HAS DROPPED TO ATMOSPHERIC AT THIS TIME.

FIGURE 4–13

4.2.3 Seal Arrangements

A single radius bag commonly used in the bow seal was unacceptable because it required material strengths higher than the current state-of-the-art. A two lobe bag was considered and rejected because it did not provide sufficient safety margins for bag strength when environmental effects (material deterioration due to ultra-violet radiation, moisture, fatigue, etc.) were taken into account. A three lobe bag, Figure 4-7, provides a satisfactory solution, allowing use of elastomer coated fabrics that industry can produce, yet retaining some of the simplicity of the single lobe bag.

Overpressure relief vents in the bow ramp limit bag pressures to not more than three times the cushion pressure value, thus insuring adequate strength margins for connections and seal materials. The sidehulls geometry represents a compromise between hull structure weight and the capacity of bow seal seams to withstand pressure loads. The sidehulls are extended forward to support sufficient end cap pressure loads to bring the seam stresses to an acceptable level ($\leq$ 3000 lbs/in), Figure 4-10 and 4-11. The lower portion of the sidehull is configured to adequately contain finger movements. Fingers are raked to an optimum angle to reduce their size and improve performance. The arrangement of the stern seal is similar to the bow seal, except no fingers are required.

4.2.4 Seal Weight Breakdown

The seal system weight is broken down to major component levels for both the bow and stern seals. Table 4-viii provides bow seal component weight estimates, and Table 4-ix gives equivalent stern seal weights.

Weight estimates are based on use of 4.5 to 5.0 feet wide panels of 170-180 oz/yd^2 elastomer coated material. A double overlap type bond seam was selected for weight estimate purposes. Selection of this readily available size panel increases the number of required seams, and thereby increases the material weight. Use of material widths approaching 20 feet can reduce fabric material weight estimates by approximately 40-50 percent.

The fabric material weights given in the tables include the weight of seams and material for bead attachments. The clamping bead inserts are shown in Figure 4-9. The clamping hardware weights are based on designs shown in this figure and made of steel.

4.2.5 Seal Risk Assessment

Risk assessment of seals generally can be related to two requirements: (1) adequate strength, and (2) adequate life. The risk of not meeting the first requirement is small since stress in seal connections can be controlled by introducing additional lobes, using vertical cables, or by reducing overpressure loads by setting lower thresholds in the pressure relief system.

Experience shows that the risk of failing to meet life requirements is primarily related to seal elements in frequent contact with the water; i.e., tips of the fingers and lower portions of the stern bag. Even though finger wear cannot be completely eliminated, the rate of wear can be kept at an acceptable level by taking advantage of recent advancements in seal material

BOW SEAL WEIGHT ESTIMATE

COMPONENT		WEIGHT, LBS
BAG		
Lobe panels (180 oz/yd^2)		7,970
Straps (170 oz/yd^2)		500
End Caps (180 oz/yd^2)		3,010
Clamping bead inserts		400
Apron (180 oz/yd^2)		480
Apron/Finger Attachment Hardware (steel)		640
	BAG	13,000
FINGERS		
Set of ten (10) (170 oz/yd^2) (Based on four seams)		28,500
Clamping bead inserts		200
	FINGERS	28,700
ATTACHMENT CLAMPS		
Bag-to-hull (steel)		5,670
Finger-to-hull (steel)		4,000
	ATTACHMENTS	9,670
	Total Bow Seal Weight Estimate	51,370

TABLE 4-viii

TABLE 4-ix
STERN SEAL WEIGHT ESTIMATE

COMPONENT		WEIGHT, LBS
BAG (Multi-Lobe)		
Lobe panels (180 oz/yd^2)		6,645
End caps (180 oz/yd^2) (Toroidal & Conical sections)		8,355
Straps (170 oz/yd^2)		250
Horizontal web (170 oz/yd^2)		4,370
Vertical web (170 oz/yd^2) (set of five)		6,750
Planning panel (180 oz/yd^2)		7,700
Fiberglass sheathing 1/16 inch thick		270
	BAG	34,340
ATTACHMENT CLAMPS		
Clamping bead inserts		400
Internal clamping hardware (steel)		1,100
Bag-to-hull (steel)		5,700
	ATTACHMENTS	7,200
	Total Stern Seal Weight Estimate	41,540

and by using flagellation suppressors, such as stiffening cables integrated into finger material. The extent of increase in finger life due to the improvements would be determined by experiments with fingers subjected to MPS cushion pressures and hoop stresses. At present, extrapolation of existing data indicates that finger wear rates will probably be within the requirements presented in Table 4-vi.

Stern bag wear is usually quite small and can be further reduced by use of fiber glass sheathing or sacrificial elastomer layers. In the past, seals occasionally were damaged when motions of metallic connecting elements caused them to come into contact with adjacent soft seal material. The damage occurred mostly in seal seams. Risk of this damage will be minimized by eliminating mechanically fastened seams and by shrouding metallic elements in rubber.

4.3 PROPULSION SYSTEM

4.3.1 Propulsion System Description

The MPS main propulsion plant consists of four independent gas turbine powered drive trains, two in each sidehull driving controllable pitch propellers through suitable reduction gearing. In addition, the outboard system in each sidehull may be selectively powered by the two aft lift fan diesel engines through a combined diesel or gas turbine (CODOG) gearbox and clutching arrangement.

The design philosophy for the propulsion plant is based on the maximum use of existing proven components. This is achieved by the selection of the proven LM-2500 gas turbines and SACM 240-V20-RVR diesel marine engines, a CODOG gearbox system based on the German F-122 Frigate proven hardware, catalog design controllable pitch propellers and other in production components for maximum reliability. This propulsion system provides the MPS exceptional flexibility to select optimum operating combinations to provide highly economical performance over the entire operating speed range up to 70 knots.

4.3.2 Propulsion System Arrangement

Figure 4-14 illustrates the propulsion system installation in each sidehull. The upper (outboard) shaft line illustrates the CODOG installation arrangement, while the lower shaft line shows the inboard gas turbine propulsion system. Figure 4-15 illustrates the CODOG installation in greater detail.

During gas turbine operations, power to the 12 foot diameter CP propeller is provided by the LM2500 engine via turbine coupling, epicyclic reduction gearbox, Syncronous Self-Shifting (SSS) clutch, CODOG reduction/combining gearbox, and appropriate shafting, bearings and thrust block. The overall reduction ratio of the gas turbine drive train is 10.02 to 1.

For diesel operation, power is transmitted to the propeller via a hydraulic clutch, flexible coupling, SSS clutch and the CODOG gearbox. The reduction ratio provided for diesel operation is 4.58 to 1. The stern seal lift fan is driven from the opposite end of the diesel engine through a clutch which is normally disengaged during diesel propulsion operation.

Figure 4-16 illustrates the inboard propeller system, which is identical to the outer except for elimination of the 4.58 to 1 stage CODOG elements.

4.3.3 Machinery Characteristics

4.3.3.1 Gas Turbine System

The LM2500 marine gas turbine engine, manufactured by General Electric, is a derivative of the TF39 military aircraft engine, which in turn is based on the CF-6 commercial turbofan engine. LM2500 engines are currently in service on the GTS Admiral William M. Callaghan, Spruance-class destroyers (DD-963), Patrol Combatant Missile Hydrofoil (PHM), and Guided Missile Frigates (FFG-7). Additionally, several allied navies are using the LM2500 engine in new ships. In most of the applications, the LM2500 engines are supplied with engine enclosures. In the MPS installation, the enclosure is replaced by a fireproof and acoustically treated engine room, which is an integral part of the ship structure.

PROPULSION SYSTEM ARRANGEMENT

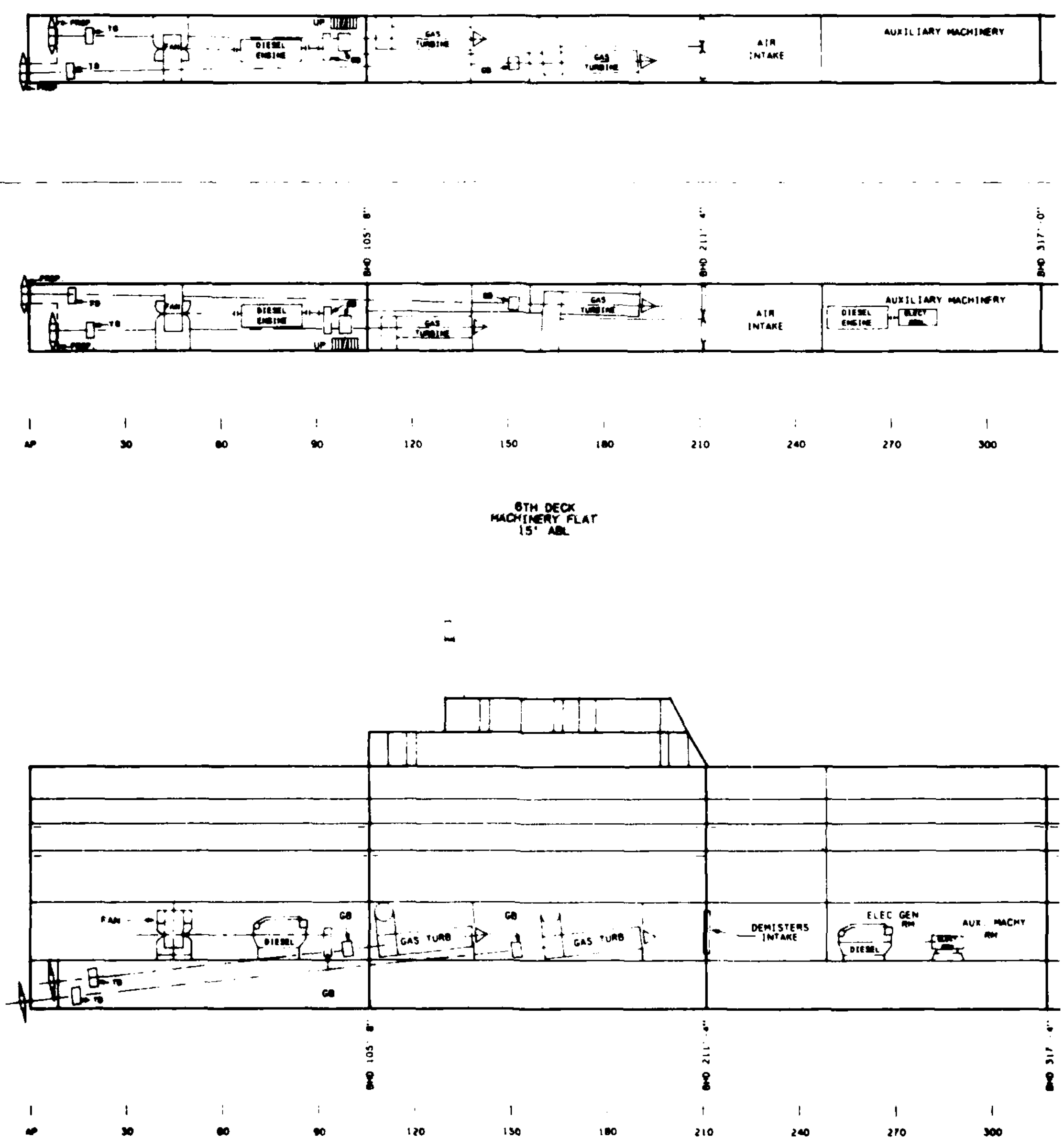


FIGURE 4–14

CODOG TURBINE REDUCTION UNIT

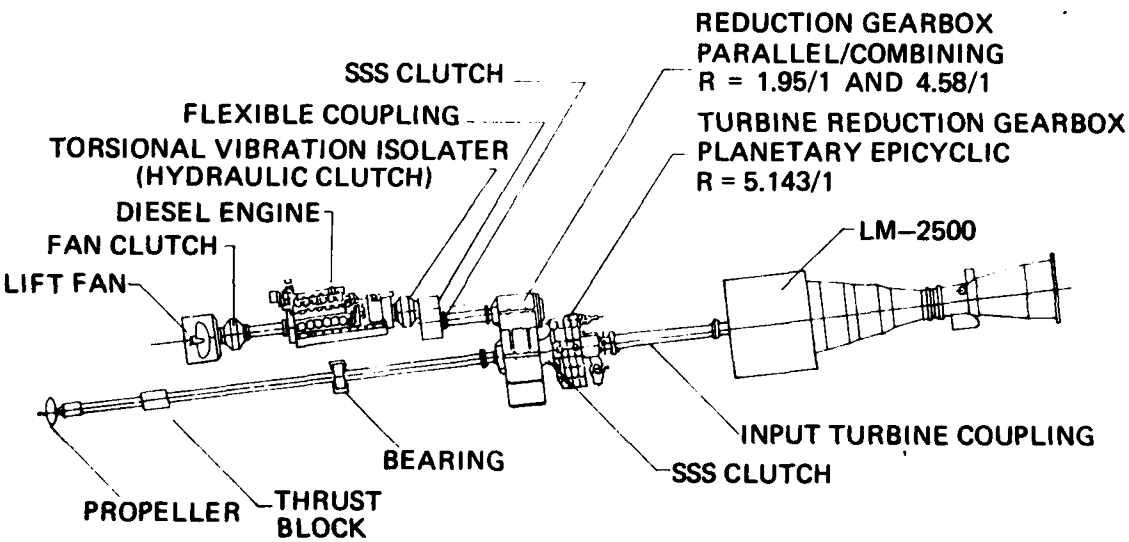


FIGURE 4–15

TURBINE REDUCTION UNIT
R = 10.02/1

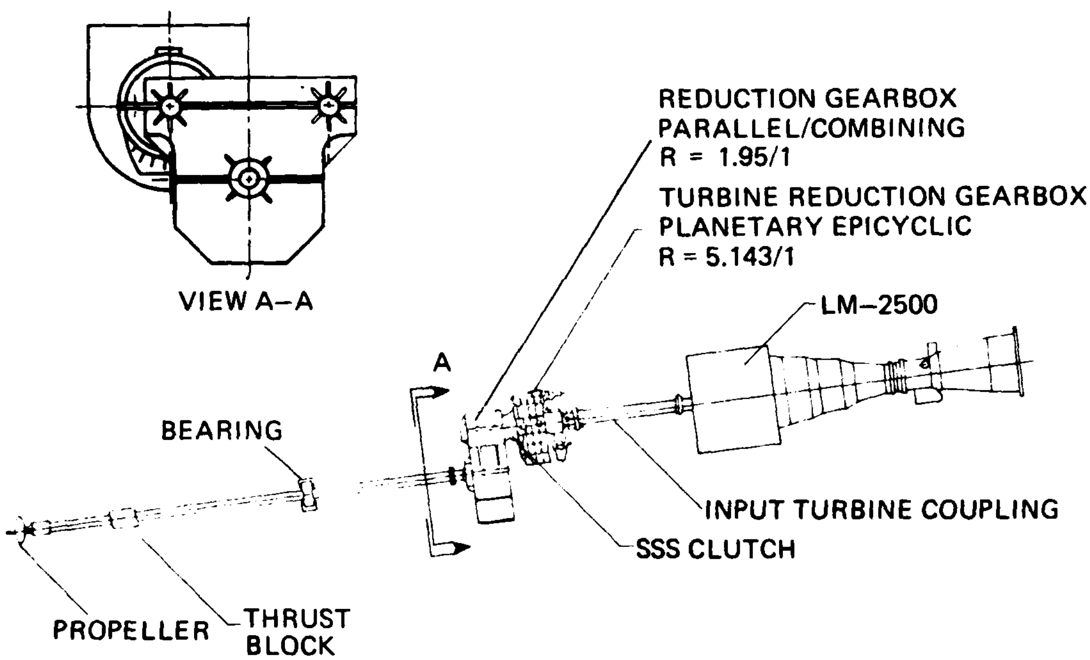


FIGURE 4–16

The LM2500 engine for MPS application has a normal power rating of 27,000 HP with an MPS mission rating of 30,000 HP. The MPS mission rating is specifically applicable to MPS mission scenarios such as a 30 day mobilization exercise when operational urgency justifies acceptance of reduced engine life. It is recognized that the selected MPS rating is about 10 percent higher than the Navy rating for the LM2500 engine (RACER Program). However, the engine has been operated up to 33,500 HP, and analysis of manufacturer's data backed by marine and offshore pumping station experience at sustained powers of 27,600 HP demonstrate that the engine is capable of reliable operation at the MPS normal power rating (27,000 SHP). These engines are guaranteed for 6000 hours mean time between failure by the manufacturer at the 27,600 HP rating. Overall, it is estimated that MPS mission power will be used considerably less than 1 percent of the time during peacetime, and up to a maximum of 600 hours during a 30 day mobilization operation while providing up to five 3900 nm round trips. Since the high power operation is projected to be a small percentage of total engine life, the MPS power rating are considered to be acceptable.

The LM2500 gas turbine engine is a two-shaft engine; one shaft for the gas generator section and one for the power turbine section. The inlet section of the LM2500 engine consists of an inlet bellmouth with a wire screen to protect the engine from foreign object damage. The bellmouth contains a water wash manifold for injecting the water and detergent solution to remove salt and other fouling residue from the compressor vanes and blades.

The power turbine is made up of six axial stages. The power turbine rotor is supported between two bearings, the rear bearing serving as both the radial support and the engine thrust bearing. This rotor rotates clockwise when facing the drive end of the engine and is aerodynamically coupled to the gas generator rotor. The exhaust collector fits around the output driveshaft and collects the exhaust gases, turns them 90 degrees into the exhaust ducts and out through the ship sides.

The engine output driveshaft incorporates dry type flexible couplings at each end. This allows the output shaft to accept lateral and angular misalignment, as well as axial thermal growth.

Figure 4-17 gives the LM2500 load curve and Figure 4-18 shows specific fuel consumption (SFC) values for the installed LM2500 for this load curve.

The gas turbines are installed on resilient mounts in a staggered side by side configuration on the port and starboard machinery platforms, as shown in Figure 4-19. Transverse and longitudinal bulkheads isolate each engine in a watertight compartment. Each compartment has fire, thermal and sound protection.

4.3.3.2 Diesel Systems

A diesel engine located aft in each sidehull drives the stern seal fans, or drives the outboard propellers during low powered cruise and maneuvering. When used in the propulsion mode the diesels are part of the CODOG systems described in Section 4.3.2. In an emergency the diesels can simultaneously drive both propellers and stern seal fans.

PROPULSOR LOAD CURVE USED FOR ENGINE PERFORMANCE CALCULATIONS

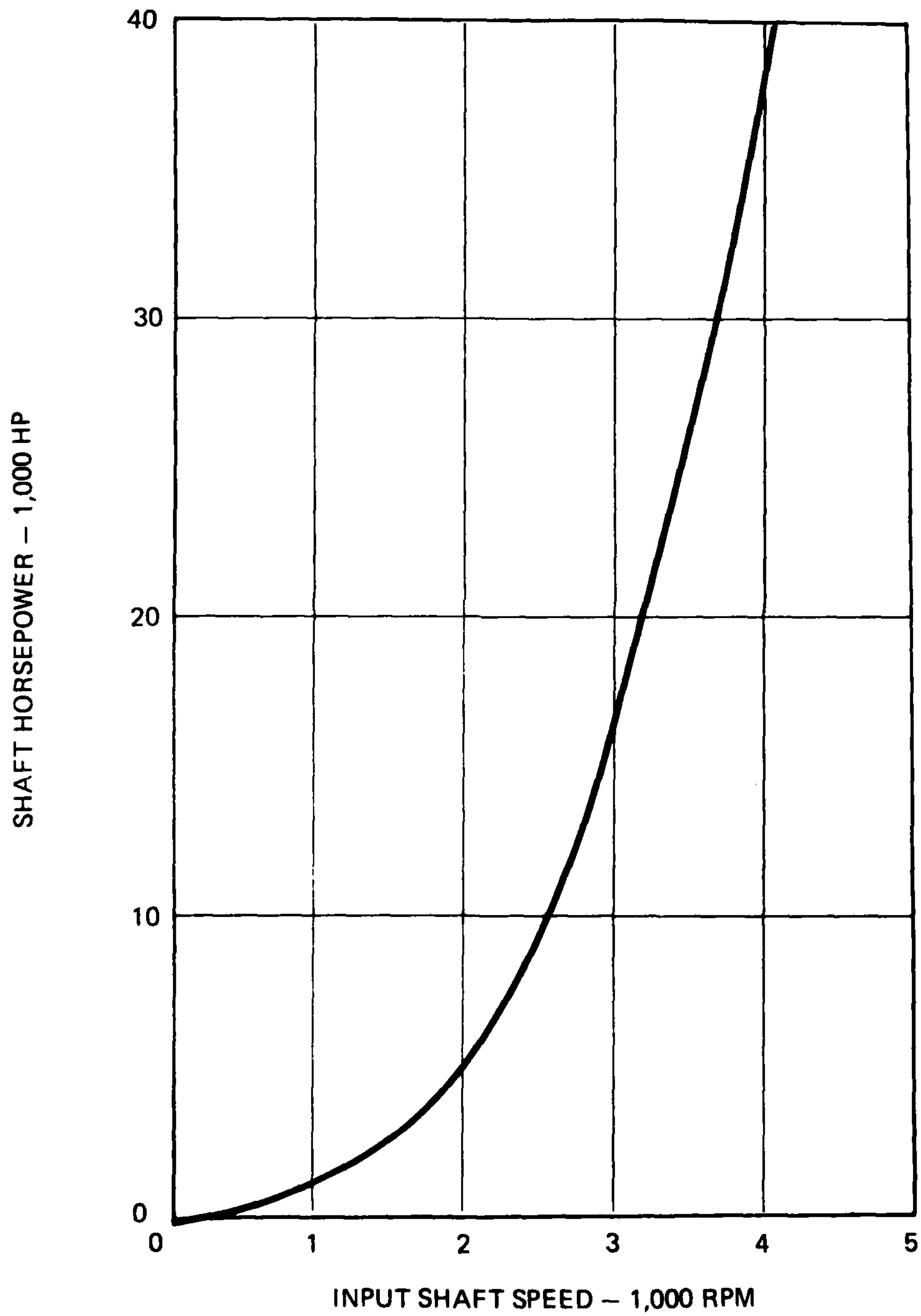


FIGURE 4–17

LM 2500 SFC VALUES FOR PROPULSION ENGINES

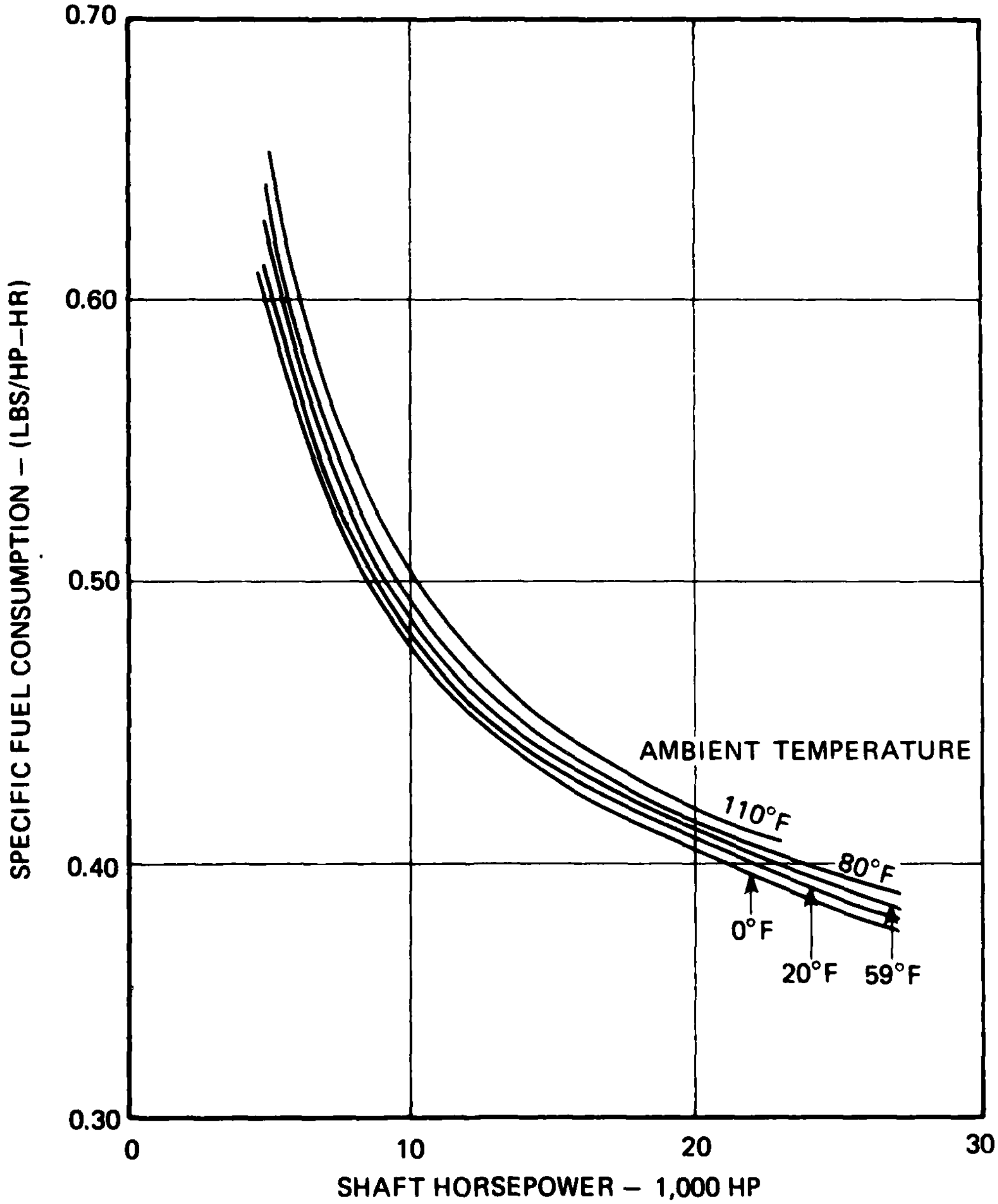
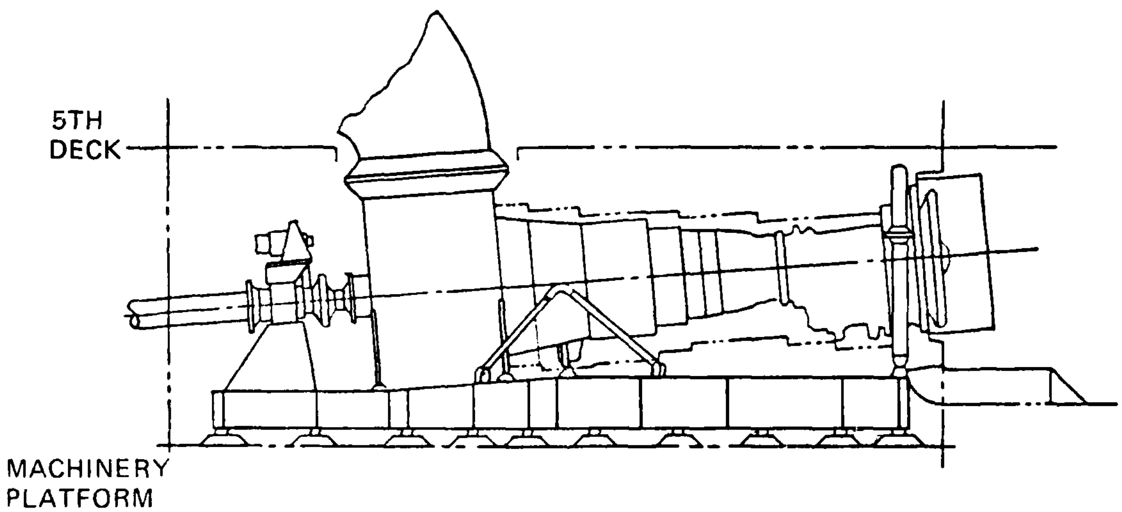


FIGURE 4–18

PROPULSION ENGINE ROOM ARRANGEMENT – ELEVATION VIEW



LM2500 ELEVATION VIEW LOOKING INBD

FIGURE 4–19

The Societe Alsacienne de Constructions Mechaniques (SACM) 240-V20-RVR diesel engine was selected because of fuel efficiency, reliability, speed and weight. It is manufactured by SACM at Mulhouse, France, and marketed in the U. S. by F. W. Donnelly Company, Houston, Texas. The engine is rated continuously at 7000 SHP at 1350 rpm with a 2 hour dash rating of 7700 SHP at 1395 rpm. Fuel consumption varies from .34 to .36 pound per shaft horsepower hour. The engine is of square design with bore and stroke of 240 mm. Long life is achieved by a reduced volumetric ratio (compression) of 9, achieved by higher dead volume at the top dead center of piston travel combined with high pressure ratio turbochargers.

Progressive maintenance is performed at 4000 hour intervals. Major maintenance is scheduled at 16,000 hours.

The engine is started with 426 psi air and is sea water cooled with 707 gallons/minute. The engine, complete with turbochargers and accessories, weighs 23 LT.

4.3.3.3 Transmission System

The CODOG gearing from the gas turbine side consists of a 5.143 to 1 planetary gear originally developed for the 3KSES by Cincinnati Gear Company, an SSS clutch and a single-stage helical gear set with 1.95 to 1 reduction gear ratio. The diesel side consists of an SSS clutch and a 2-stage helical gear providing a 4.58 to 1 reduction. The propulsion system automatically changes over from diesel engine operation to gas turbine operation when gas turbine speed at the SSS clutch exceeds diesel speed, and vice-versa, by way of SSS clutches. Figure 4-20 shows a CODOG gearing schematic, and Figure 4-21 shows its cross-section. The gas turbine unit and the gear unit are mounted separately on flexible mounts and are connected by a flexible coupling, Figure 4-20, Item (1). From the flexible coupling the power is transmitted via a connecting shaft supported by a separate bearing (2) to the tooth coupling (3). The connecting shaft is necessary with regard to the critical speed of the flexible coupling.

An epicyclic gear (4) is the entry point to the gear unit on the gas turbine side. Since all gas turbines run with the same sense of rotation, a planetary gear is provided on the starboard side and a star gear on the port side. In this way, the required reversing of the direction of rotation is achieved and an additional reversing gear is not necessary.

This 5.14 to 1 epicyclic reduction gear was originally developed in star gear configuration for the 3KSES by the Cincinnati Gear Company. All engineering through released component and assembly drawings, complete dynamic and finite element analyses are complete. Tooling and gear forgings are on hand. This gearbox configuration is lighter, more compact, and more efficient than a comparable parallel shaft design. Gear weight is minimized by means of a multiple path load transfer system made possible by use of epicyclic gearing. A light weight aluminum gear case can be used, since gear tooth loads are contained within the gear train and planet carrier and not transmitted through the gear case. A cross section of the epicyclic transmission, and a weight summary are shown in Figure 4-22. The 3KSES epicyclic gear arrangement was originally designed for 40,000 HP. At the MPS mission horsepower rating of 30,000 HP, the gearbox is a conservative design. Hydrodynamic journal bearings are used throughout for maximum reliability. The multiple path, double-helical

CODOG PROPULSION MACHINERY SCHEMATIC

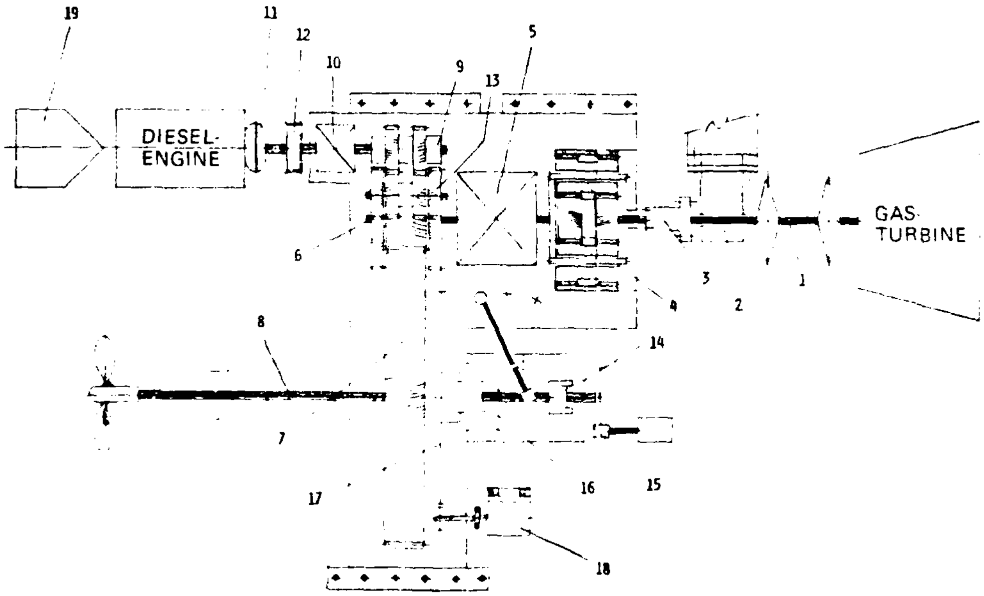


FIGURE 4–20

CODOG REDUCTION BOX

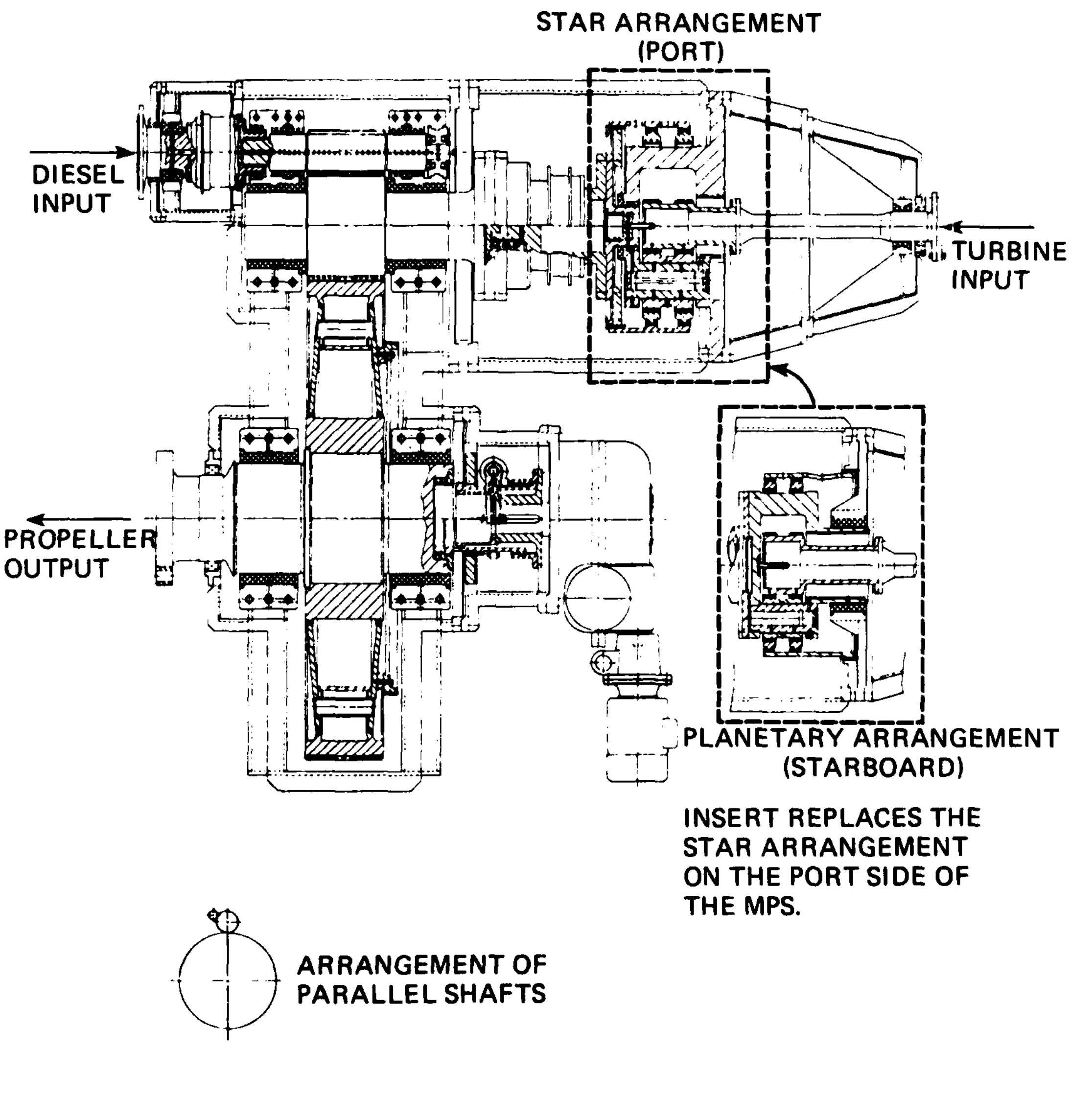
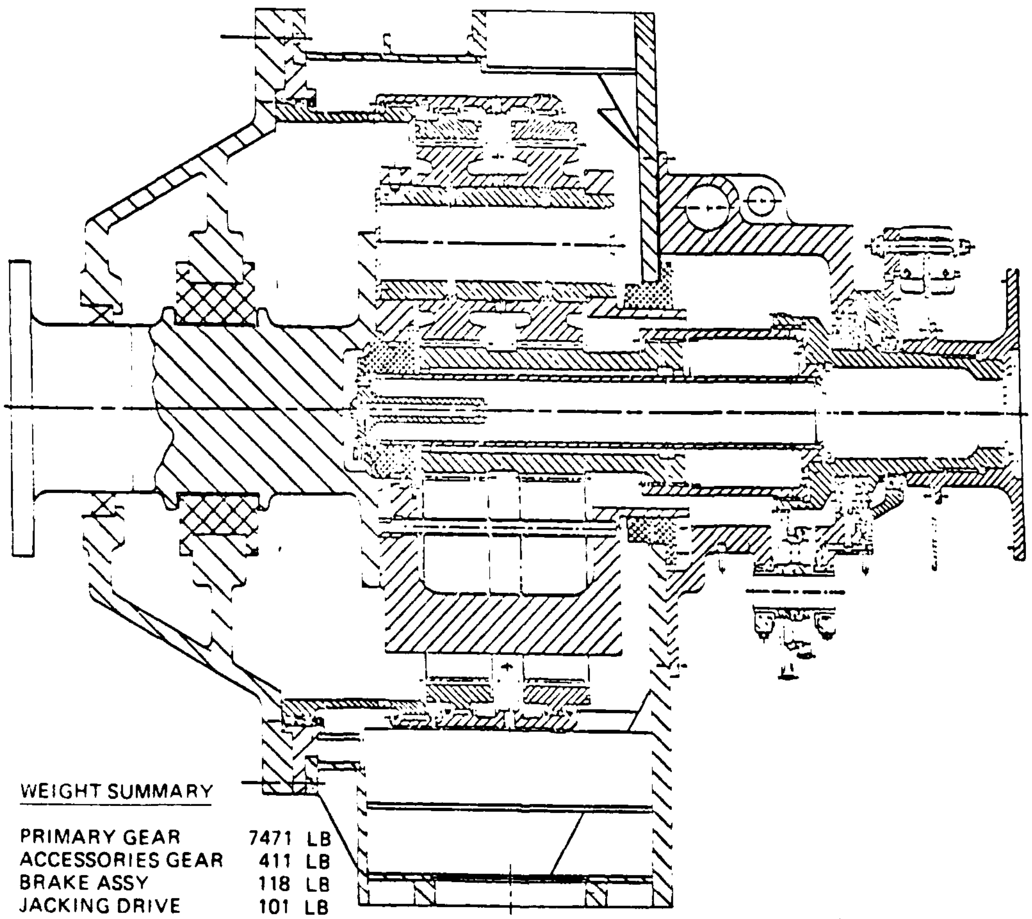


FIGURE 4–21

TURBINE REDUCTION GEARBOX
R = 5.143/1



WEIGHT SUMMARY

PRIMARY GEAR	7471	LB
ACCESSORIES GEAR	411	LB
BRAKE ASSY	118	LB
JACKING DRIVE	101	LB
LUBE SYSTEM	463	LB
	8564	LB

FIGURE 4–22

configuration comprises four planet gears, a floating sun gear, flexible annulus gearing or a single-sleeve output planet carrier torque member depending on planetary or star configuration. Load equalization is achieved by means of the Stoickicht principle, which is developed around the floating sun gear and controlled flexing of the annulus gearing and output planet carrier. Table 4-x gives transmission details.

TABLE 4-x
TRANSMISSION DETAILS

Design Point (IN)	27,000 HP	3600 RPM	472,752 in-lb
(OUT)	27,000 HP	700 RPM	2,431,300 in-lbs
	SUN	PLANET	ANNULUS
Number Teeth	35	58	145
Pitch Diameter	10.2 in	16.9 in	42.3 in
Speed	3600 RPM	1700 RPM	700 RPM
K Factor	402 PSI	90.7 PSI	
Bending Stress	2842 PSI	3675 PSI	5210 PSI

Referring again to Figure 4-20, the SSS clutch (5) is connected to the epicyclic gear. It disconnects the gas turbine and also the epicyclic gear during diesel engine operation. Thus, additional noise and friction losses otherwise caused by the idling epicyclic gear are prevented.

During gas turbine operation power is transmitted from the SSS-clutch via the pinion (6) to the main gear (7) and from there to the propeller shaft (8). In this case, the pinion (9) of the spur gear on the diesel engine side idles, thereby the second SSS-clutch (10) automatically cuts the connection to the diesel engine.

During diesel engine operation power is transmitted via a hydraulic clutch (11) and a flexible coupling (12) into the second SSS-clutch mentioned above. The flexible coupling is necessary since the diesel engine is flexibly mounted. For starting and standby diesel engine operation the hydraulic clutch is drained off to isolate the diesel, otherwise the required power for starting the diesel engine, plus the breakout torque of the complete propulsion plant would have to be generated.

The power then is transmitted from the SSS-clutch (10) via the pinion (9) and main gear (7) to the propeller shaft. The lift fan is clutched out in this propulsion mode.

Since the direction of rotation of one of the diesels has to be reversed, a reversing pinion is provided on the starboard gear. This is arranged in such a way that the distance between the diesel engine and gas turbine shafts is the same for both gear units. The port and the starboard diesels are also mounted at the same height.

During diesel engine operation the idling planetary gear friction torque prevents the power turbine rotor from turning. The drive also can be locked by a mechanical shaft brake (16). The jacking motor (15) can be switched in via an engaging gear (14).

The lube oil pumps and the hydraulic pumps for the seawater cooling pump drive, as well as the hydraulic propeller controlling device (18) are driven mechanically by the gear unit (17).

Figure 4-23 shows a cutaway view of an almost identical CODOG system currently installed with the LM2500 gas turbines for use in the German Navy F-122 class frigates. This gearbox has undergone extensive, testing and proved to be very smooth running and quiet.

4.3.3.4 Propulsor System

The final propeller design selected for the MPS evolved after consideration of many different configurations. Two design objectives influenced the selection process. Primary importance was placed on ruggedness and simplicity. The second design objective was to maximize MPS performance over its entire operating envelope that spans 0-70 knots and 5000-15,000 LT displacement.

The initial configurations examined utilized fixed-pitch propellers to maximize simplicity. For high speed operation this propeller has excellent efficiency. However, at speeds below 20 knots, the efficiency of the fixed-pitch propeller was found to be 30 percent less than that of a propeller designed for low speed operation only. Since the MPS might operate a large percentage of time during peacetime at low speed, it was considered necessary to improve low speed propeller efficiency.

A number of approaches to improve low speed efficiency were examined and found acceptable. For example, two separate fixed-pitch propellers for low speed diesel operation, in addition to the four fixed-pitch propellers for the gas turbine high speed operation, achieved the efficiencies, but at the increased cost of two extra propellers and the requirement for reversing gears.

The system finally selected for the MPS consisted of four (4) supercavitating controllable pitch (CP) propellers powered through a CODOG system gearbox capable of either diesel or gas turbine engine operation. This system maximizes MPS performance efficiency at all operating speeds and eliminates the requirement for a reversing gearbox.

A parametric study was performed by Hydronautics Incorporated utilizing a computer design program developed for the SES Project Office in 1979. Basically, the program combines linearized supercavitating foil theory with supercavitating momentum and cascade theories backed by extensive model tests. Blade section strength is calculated by a curved beam analysis, and section characteristics are continually adjusted until a satisfactory combination of structural integrity and hydrodynamic performance is achieved.

CUTAWAY OF CODOG GEARBOX

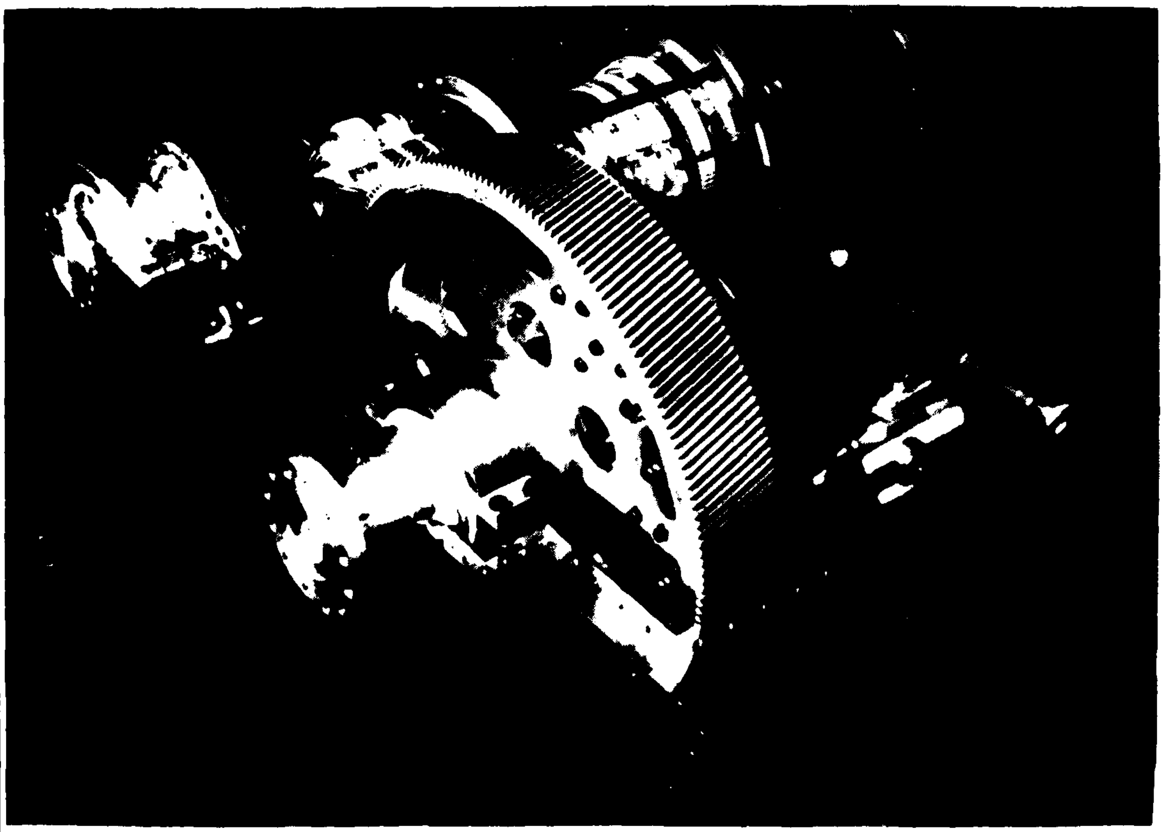


FIGURE 4–23

Results of the parametric study indicated that for the installed CODOG system, a 12-foot diameter controllable pitch propeller with a maximum rotative speed of 360 RPM is required to achieve optimum performance over the entire craft operating range. This propeller has the following characteristics:

No. Blades	4
EAR	0.60
Hub-Diam Ratio	0.35
Skew	15 degree
Maximum Stress	30000 psi (fatigue limit)

Titanium was selected for the propeller blades because of the extensive successful experience with this material in previous SES propulsors. The four foot blades are sufficiently small so as not to pose any manufacturing problems. Stainless steel blades could also be used as they have approximately the same strength and cavitation resistance characteristics as titanium. However, the heavier weight of stainless steel would add 24 LT to the total installed propeller weight.

These propellers, at 30,000 SHP and 12 foot diameter, are much smaller than the largest existing commercial propellers at 46,000 SHP and 24 foot diameter. Hundreds of commercial CP propellers in the MPS size/power range have been built and successfully operated over the last 20 years.

In addition, the USN DDG-963 and FFG-7 CP class propellers are rated at 42,000 SHP with 17 foot diameters. The Navy has accumulated over 12,000 hours on some of these propellers to date. The MPS propellers have hubs as large as these but carry only 70 percent of the horsepower and less than half the torque. This results in a very conservative propeller mechanical design that eliminates the source of problems experienced in the higher horsepower Navy installations. The SES propeller installation locates these oversize propeller hubs immediately behind the sidehull transoms which simplifies the propeller pitch control hydraulic system, shelters the hubs from impact damage, and eliminates propeller installation hydrodynamic appendage drag.

The estimated hydrodynamic performance of this propeller is shown in Figure 4-24, where thrust coefficient (KT) and efficiency (η) are functions of advance ratio (J), for various blade pitch settings. These estimates are based on a 50 percent propeller submergence level at top speed (design point) and with a fully submerged propeller for low speed conditions. With two propellers per sidewall and 27,000 SHP per propeller (including a transmission efficiency of 0.985), the estimated MPS performance is shown in Figure 3-3. Table 4-xi provides a corresponding synopsis of maximum speed, required power, propeller RPM and blade pitch setting for this configuration. The estimated performance in the off-cushion mode is also given in Table 4-xi for the 10000 LT displacement at both 28 and 20 knot speeds.

PROPELLER PERFORMANCE ENVELOPE

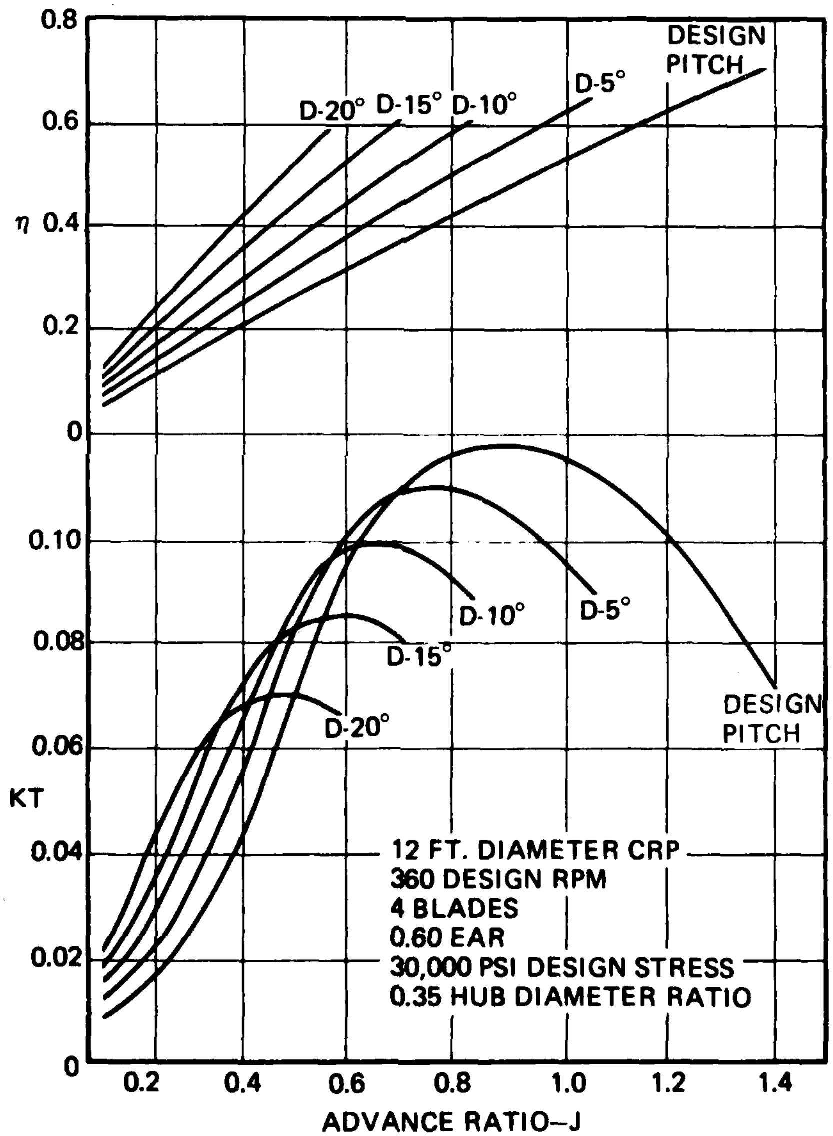


FIGURE 4–24

ESTIMATED PERFORMANCE 12 FOOT DIAMETER CONTROLLABLE PITCH
360 DESIGN RPM PROPELLER

CONFIGURATION #1: 2 Propellers/Sidewall
27580 HP/Propeller

DISPLACEMENT	APPROX. VEL.	n_p	RPM	POWER/ PROPELLER	PITCH	TOTAL THRUST
6600 LT	61 Kts.	0.70	360	27580 HP	Design	413,000 Lbs.
8500 LT	52 Kts.	0.68	360	27580 HP	D-2°	470,000 Lbs.
10000 LT	44 Kts.	0.64	360	27580 HP	D-6°	525,000 Lbs.
10000 LT*	28 Kts.	0.59	360	16213 HP	D-16°	445,000 Lbs.
10000 LT*	20 Kts.	0.62	272	4953 HP	D-20°	200,000 Lbs.
15000 LT*	28 Kts.	0.47	360	27580 HP	D-11°	600,000 Lbs.
15000 LT*	29 Kts.	0.49	360	30000 HP	D-9°	655,000 Lbs.

CONFIGURATION #2: 1 Propeller/Sidewall
27580 HP/Propeller

DISPLACEMENT	APPROX. VEL.	n_p	RPM	POWER/ PROPELLER	PITCH	TOTAL THRUST
6600 LT	39 Kts.	0.60	360	27580 HP	D-7°	227,000 Lbs.
8500 LT	25.5 Kts.	0.42	360	27580 HP	D-9°	295,000 Lbs.
10000 LT	23.5 Kts.	0.39	360	27580 HP	D-9°	295,000 Lbs.

CONFIGURATION #3: 1 Propeller/Sidewall
7000 HP/Propeller

APPROX. VEL.	n_p	RPM	POWER/ PROPELLER	PITCH	MAX. TOTAL THRUST
10 Kts.	0.26	330	7000 HP	D-20°	118,530 Lbs.
15 Kts.	0.46	295	7000 HP	D-20°	138,290 Lbs.

*Off-Cushion Drag Curve

TABLE 4-xi

4.3.3.5 Combustion Air Intake

The air inlet openings for the gas turbines are located on the weather deck on each side of the ship just forward of the deck house. Inlet design is a direct adaptation of the very efficient and well tested 3KSES combustion air system. It utilizes two (2) right angle turns to centrifuge out most water and heavy spray; with final salt moisture separation provided by 3 stage demisters.

The weather deck inlet can inject hot gas turbine exhaust gases into the free stream as needed to prevent icing. Three banks of sound suppression panel assemblies in the intake duct tune out engine noise. Demister modules remove moisture, salt and other contaminants in the air.

Bypass doors are included in the demister assembly to prevent blockage during icing conditions. Aluminum honeycomb panels on all duct walls provide smooth airflow surfaces and additional sound suppression.

The demister assembly is made up of 16 modules with 20 ft^2 of surface area per module. The 16 modules provide a growth capacity to handle either LM5000 or FT-9 engines, in addition to the baseline LM2500. Each identical module is a three stage system. The first stage is a set of corrugated vanes, which turns the air and reduces the moisture content. The second stage is a central core coalescer where smaller droplets that pass through the first stage are trapped and combined into large droplets. A final set of corrugated vanes remove large droplets formed by the second stage.

Figure 4-25 shows locations of demisters and sound suppression panels. The first set of sound suppression panels is an egg crate arrangement, formed by honeycomb acoustic panels spaced 6 inches apart. The second set of panels are arranged just below the first set of 3-inch thick honeycomb spaced 15 inches apart. The third panel set is situated behind the demisters to straighten flow to the engines, as well as provide additional noise suppression. It is identical to the second set in construction.

The sound suppression panel assemblies weigh 2000 pounds, and each demister module weighs 700 pounds. They should last the life of the ship with minimum maintenance.

4.3.3.6 Exhaust Gas Uptakes

Engine exhaust gases pass from the engine collector through a transitioning elbow and into the exhaust gas assembly. The assembly stack rises vertically to just below the wet deck where a 90 degree elbow turns the exhaust horizontally outboard to the ship's side. The duct is round in cross-section. Sixteen foot long concentric sound suppressors are installed in the vertical duct. The double walled horizontal exit section diffuses the exhaust gas. Engine room cooling air passes through this double wall to cool the exhaust duct. The entire system is also insulated. An external closure door at the exit prevents ingestion of green water during off cushion operations in high sea states. The door is closed when the engine is shut down to prevent ingestion of exhaust gas or salty air through the engine while in port or when the ship is operating on other engines.

ENGINE AIR INLET (ELEVATION VIEW)

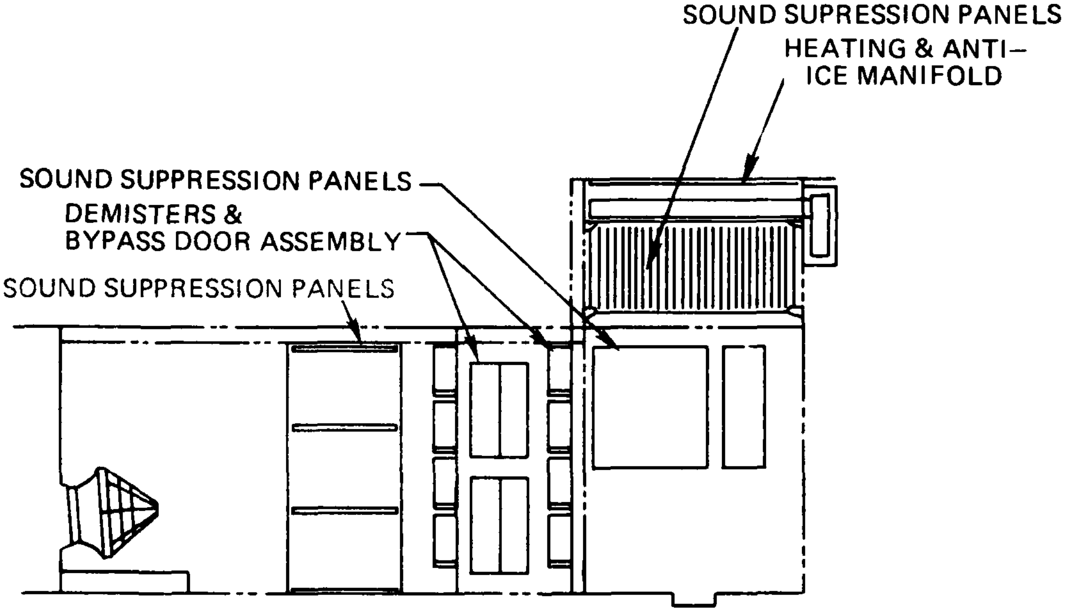


FIGURE 4–25

4.3.3.7 Propulsion Lube Oil System

Each propulsion engine has an independent lubrication system. Detail requirements for the system are specified by the engine manufacturer. A schematic of the engine lube oil system is shown in Figure 4-26. Each transmission system also has an independent lubrication system that services the propulsor thrust bearings, gearboxes, and driveline shaft/bearing modules. MIL-L-17331G (2190-TEP) lube oil provides sufficient viscosity for the journal and roller bearings. System flow requirements are based on removal of all friction heat from the components with a maximum oil temperature rise of 40 degree F. The system is non-scavenging to reduce weight and consumption of electrical power. The reservoir is sized for one minute residence time and includes electrical heaters to warm the oil to 90 degree F prior to propulsor operation. The supply pump will have excess capacity. The heat exchanger is sized to keep oil temperature below 125 degree F. An auxiliary electric motor-driven pump is used for pre and postlube as well as emergency backup.

4.3.4 Propulsion System Operation

The propulsion system is operated as a subset of the ship control system. Control is maintained from the central control console and bridge. Machinery control and performance monitoring provide the means for control and performance evaluation of principal propulsion machinery elements. The propulsion system is normally unmanned during operation; however, full control and monitoring functions are provided at the control console.

4.3.4.1 Hullborne Operation

Hullborne (or partial cushion) operations at speeds up to 16 knots are performed using diesel engines of the CODOG systems to drive the outboard propellers. Automatic SSS clutch actuators disengage the gas turbine engines and engage the diesel engines to the combining reduction gearboxes to drive the outboard propeller shafts and disengage the diesels from the stern seal lift fans. Use of economical diesels for hullborne operations is the normal mode of operation. It is possible, however, to operate off cushion with one or more of the LM2500 gas turbine engines or gas turbine/diesel combinations. A maximum hullborne speed of approximately 32 knots is attainable using the four LM2500 engines. Dockside and low speed maneuvering is accomplished by use of rudders, bow thrusters and differential propeller pitch and/or RPM.

4.3.4.2 Hump Transition

The high cushion length to beam ratio of the MPS places the primary drag hump above the maximum speed of the MPS. A relatively mild secondary drag hump is encountered at about 20 knots. Secondary hump transition will therefore be readily accomplished in response to a high power command. Secondary hump transition is possible with full cushion, partial cushion, or hullborne.

4.3.4.3 High Speed Cruise Operation

High speed cruise operation is the operational domain defined by maximum continuous power operation at displacements from full load displacement to light ship condition in the full cushion mode.

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SES MULTI-PURPOSE SHIP STUDY. TRANSPORT APPLICATION. VOLUME 1. --ETC(U)
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PROPULSION ENGINE LUBE OIL SYSTEM

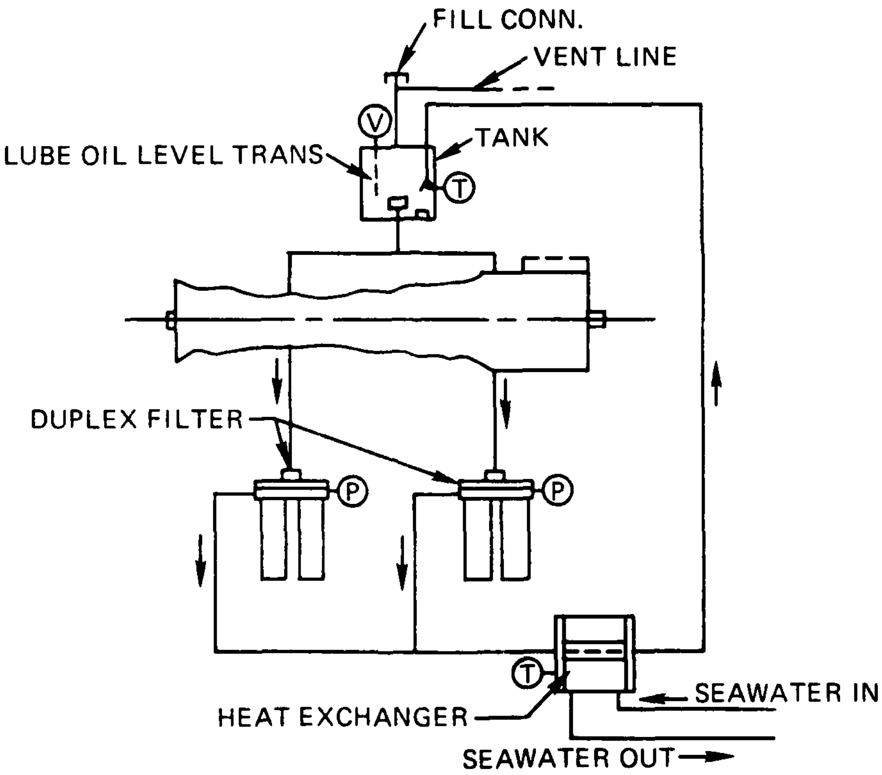


FIGURE 4–26

The MPS may be operated in either a maximum speed mode or maximum range mode. The former is based upon use of the maximum continuous horsepower available to achieve minimum time between two geographical locations within the available range. For efficient operation, propeller pitch ratio must be incrementally adjusted to respond to increases in speed that results from the decreasing displacement as fuel is consumed.

The maximum range mode of high speed cruise provides the speed profile for maximum available range through given light ship limits and is achieved by continuous or incremental adjustment of lift power, propulsion power, and propeller pitch ratio to maximize the specific range (nm per LT of fuel) at all particular displacements and sea conditions. Due to the high L_c/B_c configuration of the MPS there is only about 1 percent difference between the two modes. All performance numbers are based on the maximum power mode.

4.3.5 Propulsion Weight Breakdown

Propulsion system weights by subdivisions of SWBS Group 200 weight are presented in Table 4-xii.

WEIGHT OF PROPULSION PLANT
SWBS GROUP 200

SWBS GROUP	ITEM	WEIGHT
234	Propulsion Turbines	23
241	Reduction Gearing	120
242	Clutches and Couplings	4
243	Shafting	13
244	Bearings	12
245	Propellers	30
251	Combustion Air System	24
252	Propulsion Control	1
259	Exhaust System	15
261	Fuel Service	1
262	Lube Oil Service	7
298	Operating Fluids	4
299	Repair Parts	1
	Total Propulsion System	255

TABLE 4-xii

4.3.6 Propulsion System Risk Assessment

Propulsion system technical risk is considered to be sufficiently low so as not to place any constraints on MPS development.

The LM2500 prime mover is Navy qualified, with extensive domestic and foreign service and industrial experience. Fully developed logistics support for the engine is in operation. The SACM diesel engine is marketed world wide. Additional diesels in the required power/speed/ weight range are also available. The MPS application of the Cincinnati Gear 3KSES epicyclic reduction gear discussed in Section 4.3.3.3 is of conservative design and will be operated at less than 75 percent of its design power and at lower speeds. The rest of the combining transmission is a single and double helical state-of-the-art offset gearbox and can be readily procured from several reliable sources.

The propeller installation involves a low risk design effort. CP propellers powered by LM2500 engines are in common use in the U. S. Navy, U. S. Coast Guard, and NATO Navies. In most cases, two LM2500 engines totaling better than 40,000 SHP are geared to a single CP propeller. The 30,000 HP MPS propeller installation (behind the side hulls) allows a large hub diameter, which reduces stresses in the CP actuators without increasing hydrodynamic drag. This large hub-to-blade tip diameter ratio resulted in many trouble free years of CP operation on the SES-100B.

Overall, the MPS propulsion installation risk is evaluated as low. In fact, this installation requires no more technology than any other modern conventional monohull RO/RO ship.

4.4 LIFT SYSTEM

4.4.1 Lift System Description

The lift system consists of six independent sets of lift machinery, air distribution elements, and ride control equipment as shown schematically in Figure 4-27. They are arranged in both sidehulls from bow to stern to form independent redundant air supply systems for the bow seal, air cushion and stern seal. The two forward fans supply the bow seal; the two middle fans supply the cushion; and the aft fans supply the stern seal with lift air.

Each set consists of an Aerophysics Incorporated Rotating Diffuser (RD) Double Inlet Double Width (DIDW) fan with radially placed Inlet Guide Vanes (IGVs). Power is supplied to each lift fan by one SACM 240-V20-RVR 7000 HP diesel engine with appropriate step-up gearbox. No cross-connection exists between the six sets of lift machinery.

The aft two sets of lift machinery are located one in each sidehull near the stern seal, and serve dual functions. During low power operations the diesel engines supply power for the CODOG propulsion system through gearboxes connected to the main drive machinery. These diesels can simultaneously drive both the stern fans and outboard propellers.

MACHINERY ARRANGEMENT

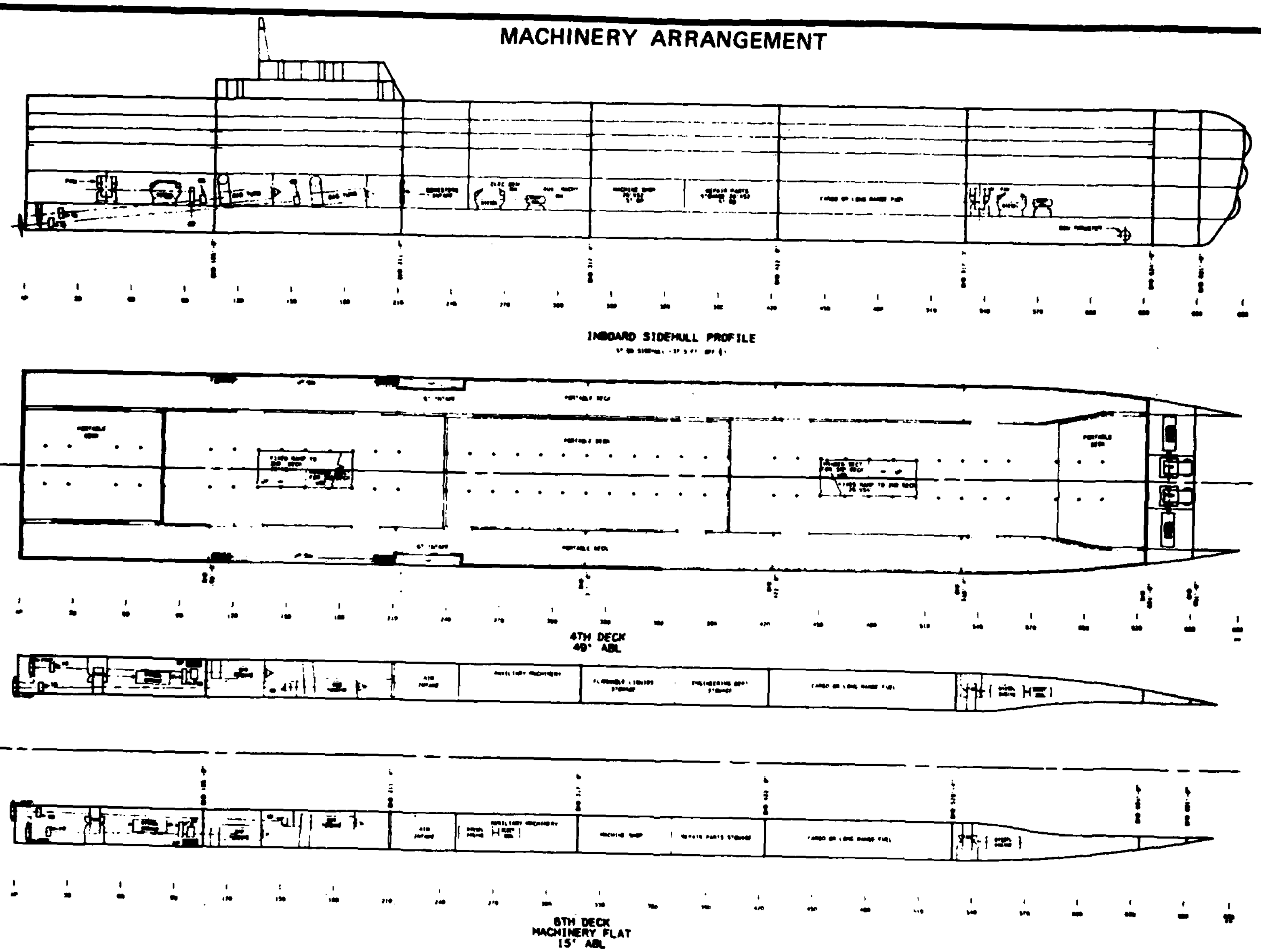


FIGURE 4–27

One of the other four fan engines serves as a power supply for the ship's alternate generator set. The fan intakes are distributed throughout the ship's vehicle cargo decks to provide the necessary compartment ventilation. This provides significant energy saving by eliminating the large separate air ventilation system required by a RO/RO ship.

4.4.2 Lift System Arrangement

Figure 4-28 provides a detailed illustration of one of the six lift system machinery sets installed in the MPS. These six sets, together with appropriate ducting, valving, bow and stern seals, and controls, comprise the lift system.

4.4.3 Lift System Components and Characteristics

4.4.3.1 Prime Movers

The SACM 240-V20 RVR 20 cylinder marine diesel engine is described in Section 4.3.3.2.

4.4.3.2 Gearbox

Lift gearboxes provide speed increase and power transmission from the diesel engines to the lift fans. Preliminary design arrangements and calculations have been performed. The design is simple and conservative with a gear ratio of 1/1.4. The gearbox assembly includes the following components:

a. Gearing of double helical design of modified involute form machined from non-welded CEVM 9310 forgings.

b. Single input shaft with flanged coupling driving through parallel shafting and associated gears to a single output shaft with flanged couplings

c. Housing or casing enclosing all gears (mounting and lifting) provisions included).

d. Two auxiliary gear driven output shafts and mounting provisions for two hydraulic pumps located on the output side of the housing.

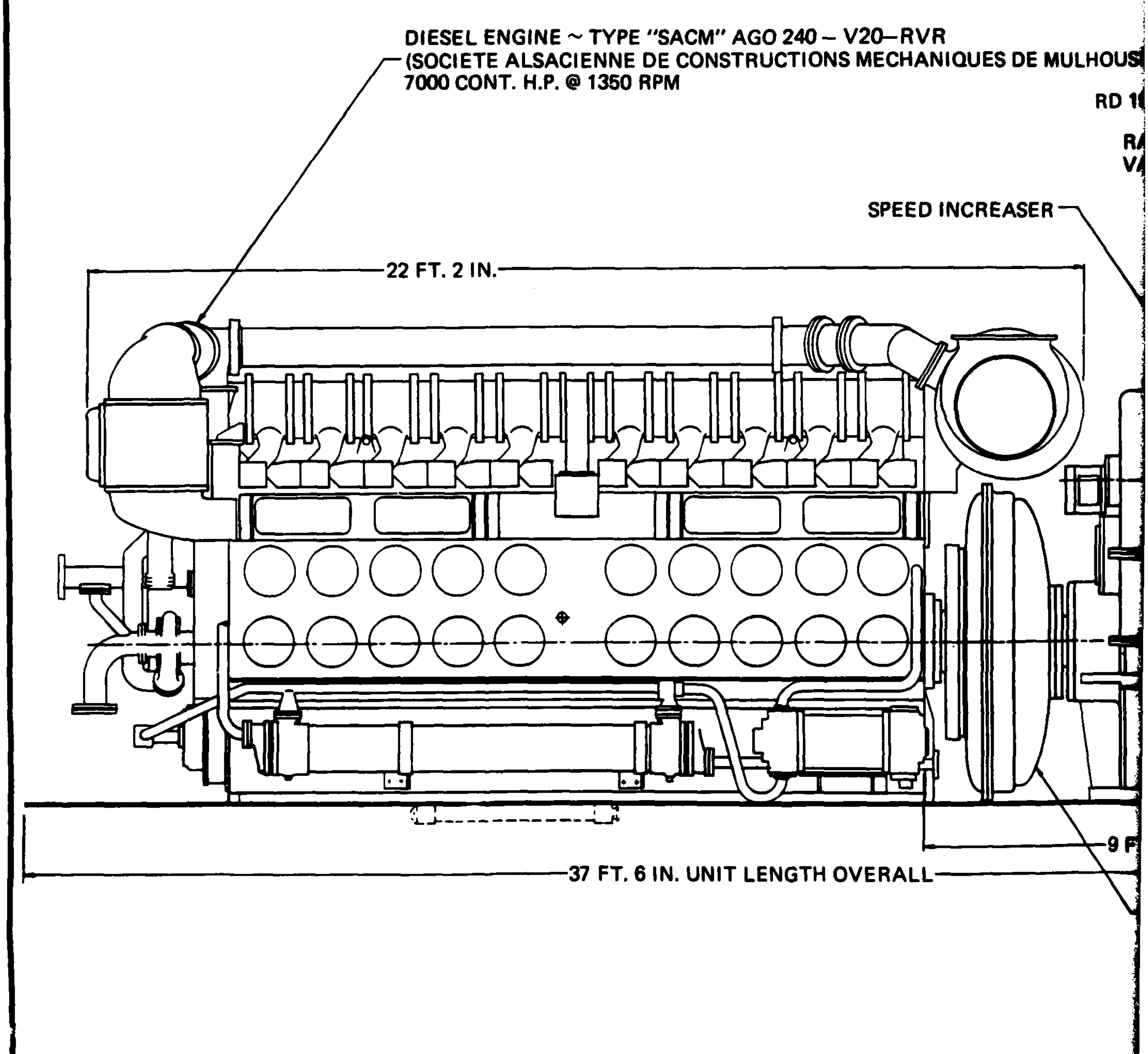
e. An attached shaft lock brake for the lift power transmission system with a torque capacity of 120,000 in-lbs on the input shaft.

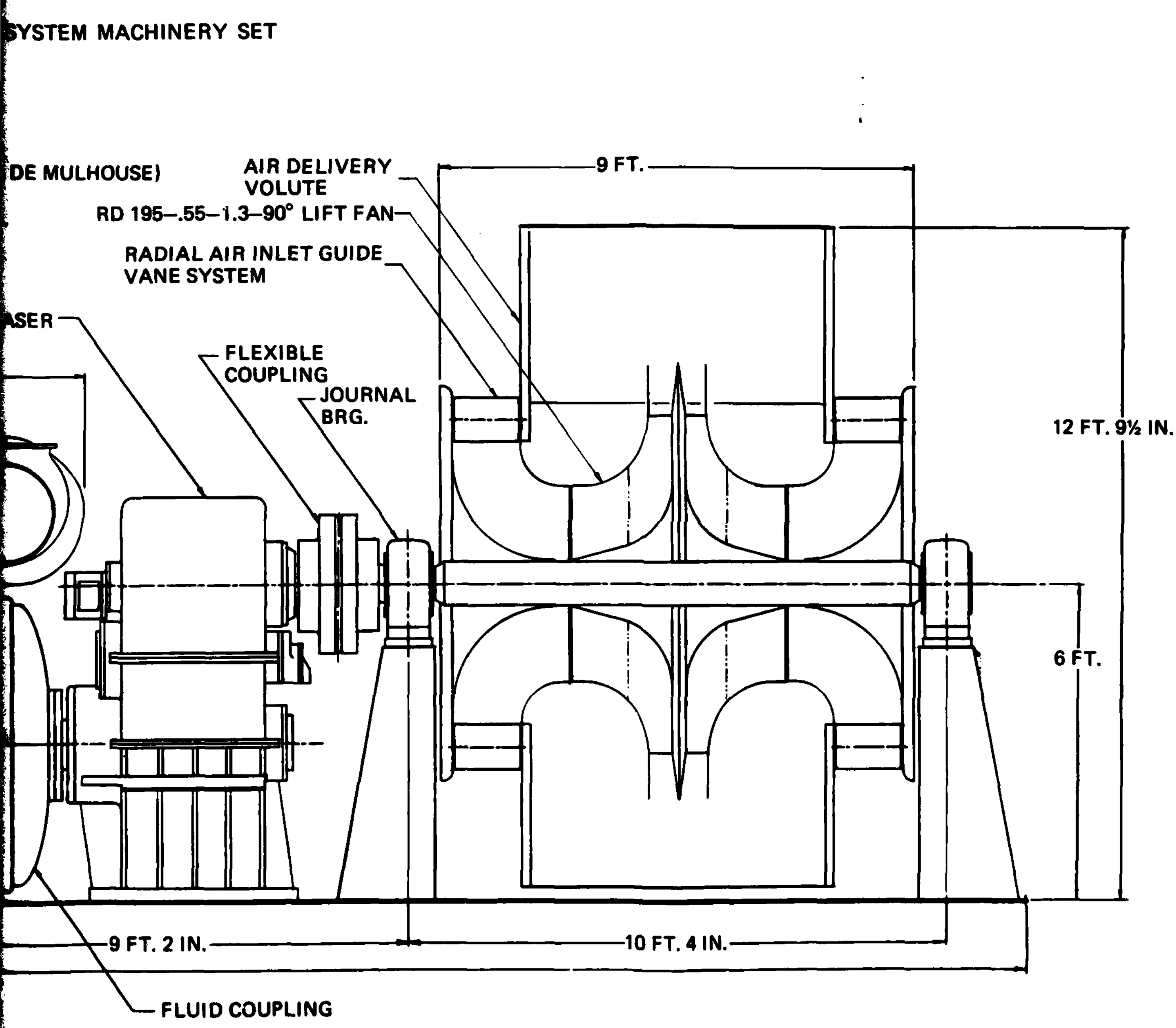
f. Installed gear driven displacement type oil pumps (supply and scavenge). The supply pump provides sufficient capacity for lubrication of the gearbox plus the fan driven by the gearbox. Additional scavenge pumps are provided for the fans.

g. Integral instrumentation for all critical parameters.

The accessory drive is designed as a self contained, detachable gearbox. It can be removed and replaced without disassembly of the pumps or gears. Bearings, removeable sumps, oil shields, brakes, and many other small components are also interchangeable.

LIFT SYSTEM MAC





SIDE ELEVATION

FIGURE 4–28

Where possible, parts are unitized to eliminate joints that might fret or sustain assembly or operating damage. Design allowables used in rotating components are below the crack propagation threshold and/o: ` low infinite life fatigue limits to ensure against material failures.

The gearbox is capable of carrying and sustaining all variable, unidirectional loads, including an additional overload factor of 1.5 for a life of at least 45,000 hours. The power efficiency of the gearbox has been calculated to be 99.26 percent. This efficiency does not include accessory power.

4.4.3.3 Lift Fan

Lift fans provide the airflow and pressure rise to the air cushion and seals for aerostatic support of the ship compatible with cushionborne performance. Each fan is a double suction single discharge rotating diffuser type fan. All design performance requirements are met by six fans having a diameter at the blade trailing edge of approximately 7 feet, or 195 cm.

The Aerophysics, Incorporated rotating diffuser (RD) fan shown in Figures 4-29 and 4-30 has been successfully used for many years in industrial applications, and has been selected for the MPS. Use of the RD fan on air cushion supported platforms was first investigated in studies sponsored by the U.S. Army in the mid 1960s. These included the design, fabrication, and spin testing of a 5.5 foot diameter lightweight fan constructed entirely of aluminum using aircraft type riveted construction. Following these early investigations, development of the RD fan was extended to very large sizes, Figure 4-31. Under the 3KSES contract, the detailed design of a lightweight lift fan was completed. The fan was under full-scale construction when the 3KSES program was terminated. In addition, dynamic tests of a large scale model RD fan were completed at the David Taylor Naval Research and Development Center (DTNSRDC). These tests included evaluation of the fan's performance in the unsteady SES marine environment. The conclusion drawn from the DTNSRDC tests was that the behavior of the RD fans is well suited for the SES environment.

The RD lift fan for the MPS is of an existing design shown in Figure 4-29 that has been in operation since 1974. Performance data was obtained from direct full scale measurements utilizing an approved ASTM code tester. Fan data is complete, including flow variations achieved with the radially installed inlet guide vanes. Tables 4-xiii and 4-xiv detail the fan's operating range of pressure and flow. The fan is capable of lifting the MPS by operating at pressures to 800 PSF. The pressure versus flow curve is smooth with no positive slope regions to cause instabilities or stalling. Figure 4-32 shows the measured fan operating map complete with the effects of IGVs. Full scale efficiencies of 88 percent are achieved. Note the wide range of performance above 80 percent efficiency. Operating points are shown for 10,000 and 15,000 LT displacements.

The fan impeller is a centrifugal discharge impeller with an integral axial inducer inlet. The center disk and outer shrouds extend some 30 percent beyond the blade trailing edges to form the rotating diffuser air passage. Blades are flat plates rather than airfoil blades and are installed axially in the inlet portion. At the impeller discharge the blades are radial to eliminate bending

MPS TYPE LIFT FAN DURING INSTALLATION

FIGURE 4–29

MPS LIFT FAN – SIDE VIEW

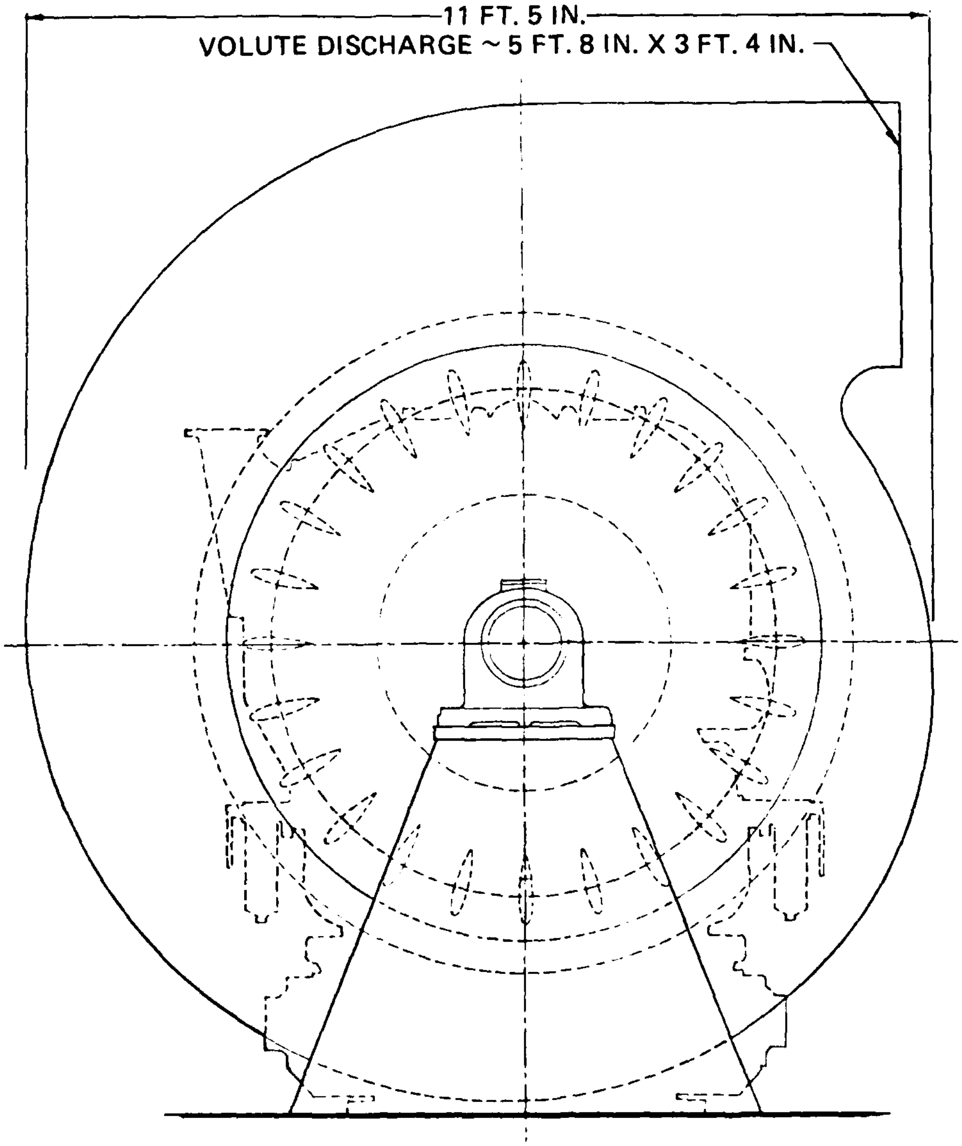


FIGURE 4–30

ROTARY DIFFUSER FAN DURING ASSEMBLY

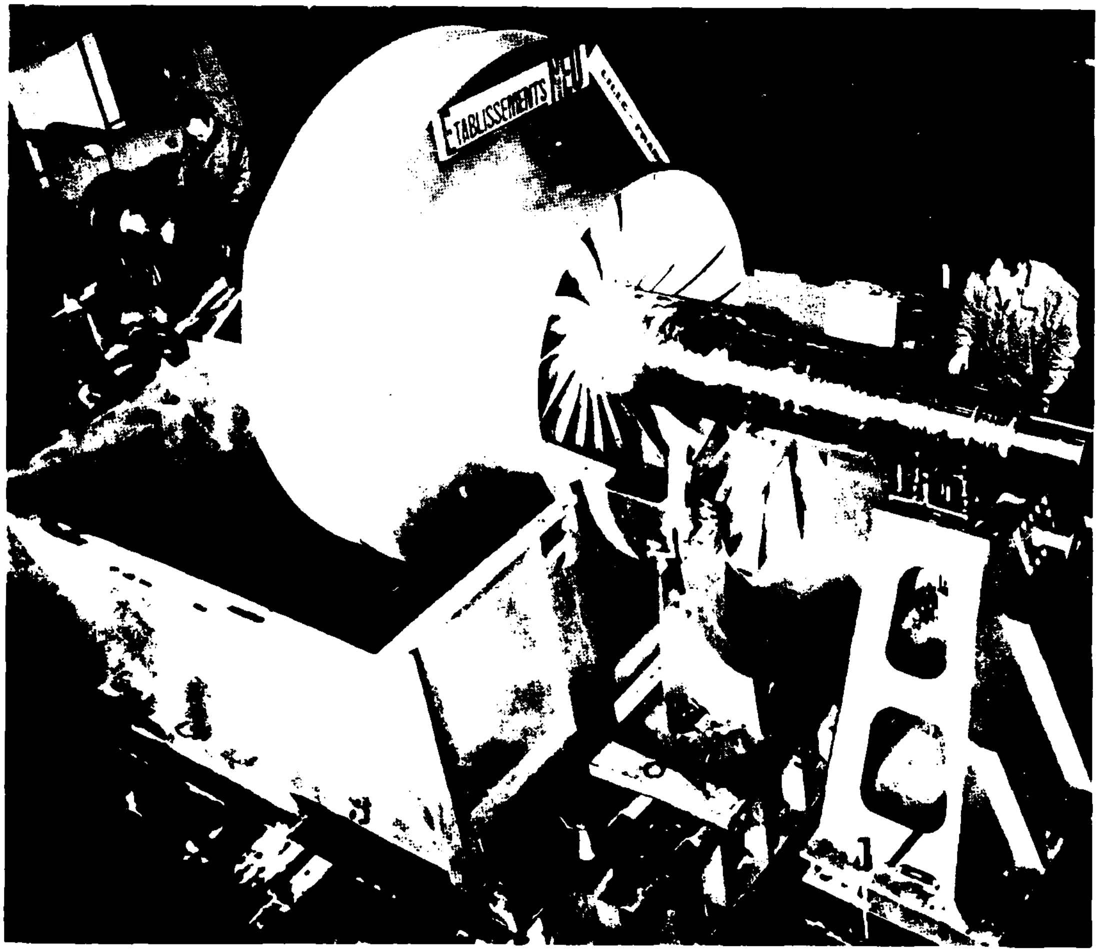
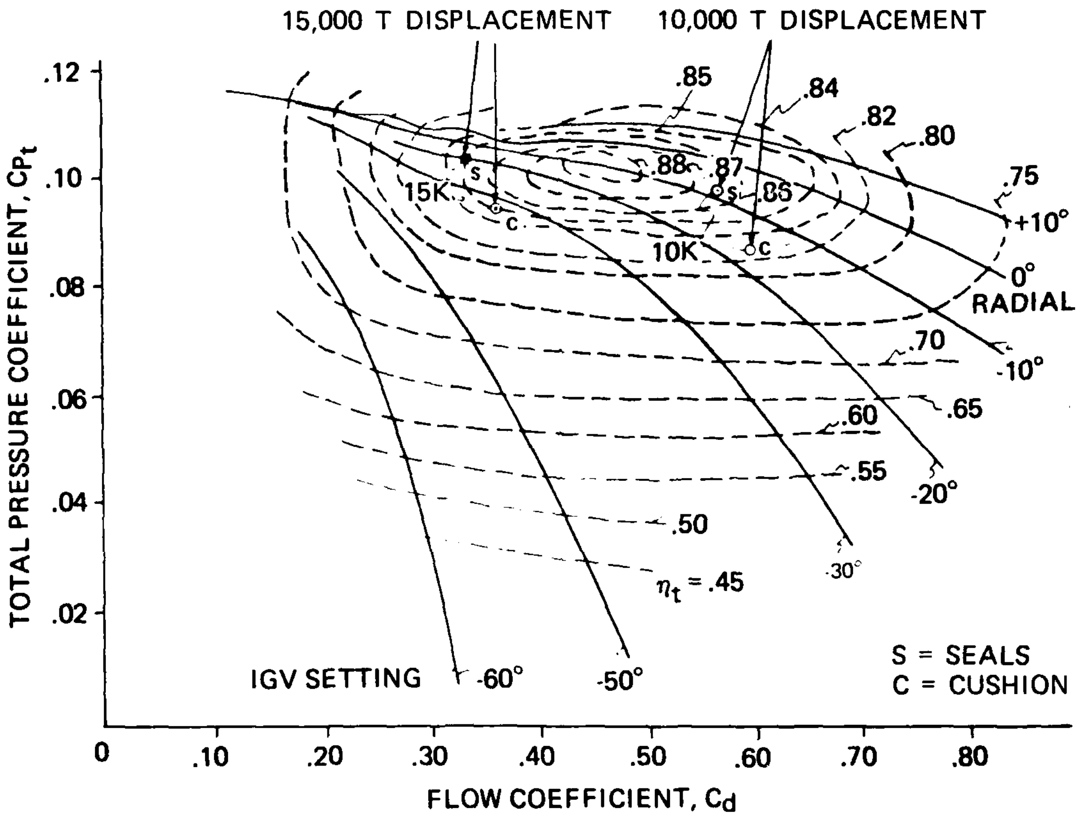


FIGURE 4–31

GENERAL PERFORMANCE OF FULL SIZE RD WHEEL



SERIES RD 195–.55–1.3–90°
80°F TEMP
50% REL. HUMIDITY

FIGURE 4–32

LIFT SYSTEM PERFORMANCE REQUIREMENTS
(10,000 LT)

SUB-SYSTEM	SEALS	CUSHION
NO. OF DWDI RD LIFT FANS	4	2
NO. OF INLETS	8	4
HORSE POWER AVAILABLE/INLET	3500	3500
P_S STATIC, PSF	514	467
P_T TOTAL, PSF	555	504
DELIVERED FLOW/INLET, CFS	2917	3120
TOTAL FLOW IN CUSHION, CFS	--	12480
TOTAL FLOW IN BOTH SEALS, CFS	23336	--
TOTAL FLOW/SHIP, CFS	35815	
C_{Pt}, TOTAL PRESSURE COEFFICIENT	.0970	.0881
C_d, FLOW COEFFICIENT	.551	.584
N_t, TOTAL EFFICIENCY	.865	.825
IGV BLADE SETTING, DEGREES	-9	-16
SLOPE OF PERFORMANCE CURVE	STABLE	STABLE
TIP SPEED, FT/SECOND	549	
RPM, ENGINE - FAN	1350 - 1639	
GEAR RATIO REQUIRED	1.214	

TABLE 4-xiii

LIFT SYSTEM PERFORMANCE REQUIREMENTS
(15,000 LT)

SUB-SYSTEM	SEALS	CUSHION
NO. OF DWDI RD LIFT FANS	4	2
NO. OF INLETS	8	4
HORSE POWER AVAILABLE/INLET	3500	3500
P_S STATIC, PSF	700	700
P_T TOTAL, PSF	808	735
DELIVERED FLOW/INLET, CFS	2191	2190
TOTAL FLOW IN CUSHION, CFS	--	8762
TOTAL FLOW IN BOTH SEALS, CFS	17528	--
TOTAL FLOW/SHIP, CFS	26290	
C_{Pt}, TOTAL PRESSURE COEFFICIENT	.1050	.0955
C_d, FLOW COEFFICIENT	.322	.354
N_t, TOTAL EFFICIENCY	.850	.850
IGV BLADE SETTING, DEGREES	-10	-32
SLOPE OF PERFORMANCE CURVE	STABLE	STABLE
TIP SPEED, FT/SECOND	636	
RPM, ENGINE - FAN	1350 - 1900	
GEAR RATIO REQUIRED	1.407	

TABLE 4-xiv

stresses. The flat plate blades facilitate economical construction and long life. The fan volute is a conventional rectangular volute. The fan inlet is directly coupled to a high efficiency ram recovery inlet duct. Inlet guide vanes are arranged in a radial torus in this duct. This configuration results in a shorter overall length in comparison to a fan configured with axial inlet guide vanes. The inlet caisson configuration also results in a quieter fan, as shown by noise level measurements in Figure 4-33. The MPS fan noise levels are below the ISO 85 decible level for non ear protected spaces.

The rotating diffuser fan requires no development preparatory to use in the MPS.

An off-the-shelf industrial type fan can be utilized on the MPS with an acceptable weight penalty because of the large size and lower speed requirements of the ship. This fact, together with the extensive operating history of this large type of fan (over 3,000,000 hours) provides the MPS with a development risk-free lift fan.

4.4.3.4 Lift Air Intake System

Intake air to the six lift fan sets will initially be taken in through a large volume air trunk system that passes upward from the intake plenum room through the various deck levels, to a flush intake grill and valve entry on the ship main deck and upper sidehull surface. As this air trunk passes through each deck level, it provides grilled openings in the overhead portion of the interior cargo spaces. These local intakes also accommodate controllable air balance valves.

With these air trunk and inlets distributed throughout the various deck levels and stations, it now becomes possible to use the intake lift fan air as the source for the ship's interior ventilation and air conditioning.

The key to this double utility is to balance or tune the ventilation exhaust requirements to the demands of the lift fans. The use of local balance valves at the various intakes and a system of diverter valves at the topside deck intake, make this possible. Valve arrangements throughout are interconnected for environmental control and to redirect airflow in the case of shipboard fire.

The use of the lift fans for cargo deck exhaust is particularly useful when vehicles are in motion within the interior of the ship.

The lift fan and diesel engine is a unified module in an essentially air tight room fed from above by the inlet air trunk. The volume and clearances of this plenum allow free air flow into the inlet guide vane system. Any water that might enter the topside intake would settle in this room and be discharge overboard through the deck drainage system. The placement of diesel engine, gearbox, and other drive train elements within this volume allows for a secondary cooling air flow over these elements. Like the uptake, this room is structured to resist lower than atmospheric pressure on its boundaries.

FAN NOISE CHARACTERISTICS
NOISE LEVEL MEASUREMENT OF DWDI RD FAN
TIP SPEED – 528 FT/SEC

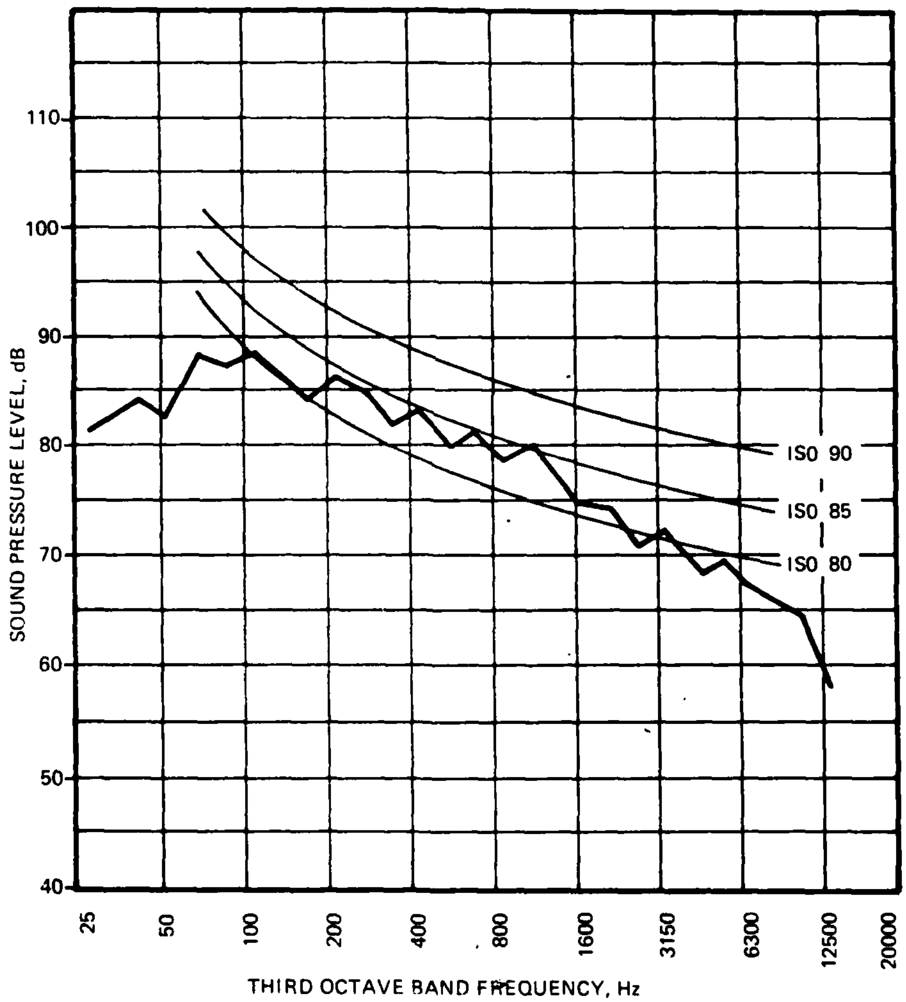


FIGURE 4–33

4.4.3.5 Lift Air Distribution System

The lift air intake and distribution system accepts incoming ambient air at the weather deck and cargo decks, routes it to the lift fans, and then to the cushion and seals. In order to regulate the stern seal pressure relative to the cushion pressure, a transfer duct with a control valve between the stern seal and cushion augments fixed orifices in the stern seal. The lift air intake and distribution system also provide airborne noise attenuation for the lift fan inlets. Shut-off valves in the distribution ducts down stream of each fan forestall flooding of the fans when the ship is off-cushion in high seas, as well as prevent back flow from the cushion or seal if the fan is shut down during on-cushion operation. The intakes also have appropriate valves and openings to serve as the primary cargo space ventilation.

4.4.4 Lift System Operation

The lift system is operated as a subset of the ship control system, and control is maintained from the central control console and bridge. Machinery control and performance monitoring provide the means for control of individual fans and flow distribution devices and provide performance evaluation of principal lift system elements. The lift system is unmanned during operation.

The ship can operate on-cushion with any combination of the six fans. Maximum system efficiency at high speed and in rough seas is achieved with all six fans. This flexibility ensures almost 100 percent lift system availability. Even the loss of four fans increases ship drag by only 20-30 percent, which merely reduces top speed proportionately. Secondary hump transition is possible with full-cushion, partial-cushion, or even off-cushion, and is therefore independent of fan performance.

4.4.5 Lift System Weight Breakdown

Estimated weight of lift system components is presented in Table 4-xv. The total lift system weight is 284 LT.

4.4.6 Lift System Risk Assessment

Overall, the risk associated with the lift system is assessed to be low as indicated below and as supported in the preceding text.

Engines	-	No risk. Engines are currently in production and marine use.
Transmission	-	Low risk. Gearbox detail design is straight forward. The low power and reduction ratio keeps the system simple and within several manufacturers' stock series. Performance estimates will be verified by test of first unit.
Lift Fans	-	No risk. Rotating diffuser fans have been built for duty points that meet those required for the MPS. Successful fan operation has demonstrated their reliability.
Lift Air Distribution System	-	No risk. This is a straight-forward design exercise.

WEIGHT OF LIFT SYSTEM MPS GROUP 567

LIFT SYSTEM	WEIGHT LBS.	WEIGHT LT	
Fan System Subbase (6)	49,861		
Demister	2,780		
Exhaust	1,000		
Sound Attenuation	432		
Shafting	4,000		
Fans (6 DWDI)	79,200		
Weather Inlets	17,710		
Air Distribution Ducts	10,000		
Air Valves, Distribution Ducts	4,576		
Vent System	4,996		
Fuel Oil Connect	120		
Lube Tanks	2,760		
Engine Controls	200		
Lube Oil Pumps for Fans	4,000		
Shaft Brakes & Torque Meter	376		
Electrical Connector	21		
	1,820,426	81	
6 SACM 240-V20-RVR DIESEL Engines with GB and All Accessories		162	
		243	243
Bow Seal			22.5
Stern Seal			18.5
TOTAL LIFT SYSTEM			284.0

TABLE 4-xv

4.5 ELECTRICAL SYSTEM

The electrical system is a conservative design with adequate capacity to supply anticipated electrical loads. The system satisfies those specifications and practice prescribed in the U.S. Department of Commerce "Standard Specification for Merchant Ship Construction".

4.5.1 Electrical System Description

Primary electrical power is supplied by a single diesel driven generator set of 1210 KW capacity. A second generator of identical configuration and capacity serves as standby; however, this generator is driven by a power takeoff from one of the lift fan diesels. A gas turbine driven generator set of 200 KW capacity serves as an emergency generator.

The distribution system provides an operational choice of ring-bus or split-plant operation. Two ship service switchboards, one for the main generator and one for the standby generator, are supplied. A third switchboard is provided for the emergency generator.

The lighting arrangement is based upon division of the ship into four lighting zones or "cubes". Three cubes comprise the internal illumination distribution system, while the fourth cube services specialized needs such as electrically powered auxiliary systems. Lights throughout the ship are predominantly of the fluorescent type.

A 3-phase shore connection feeder is provided from the main switchboard to a shore connection box. Interlocking between the shore connection and the switchboard mounted shore power circuit breaker prohibits make-or-break of the shore connection under load.

4.5.2 Electrical System Arrangement

The main and standby generator sets and their switchboards are located respectively on the starboard and port sides of the fourth deck. Secondary panels or boards are distributed throughout the ship in such a manner as to minimize cable runs.

4.5.3 Electrical System Characteristics

Engine room auxiliaries, shop equipment, ventilation, deck machinery, commissary equipment and similar equipment are, in general, energized from separate power control boards, which are in turn supplied by individual feeder lines from the main ship service generator and distribution switchbord. Emergency equipment is also fed by a similar arrangement from an emergency generator and distribution switchboard. The main and standby generator are each capable of generating 1210 KW. Primary power is generated at 480 volts, 3 phase, and 60 Hz corresponding to a nominal supply voltage of 460 volts. Power for normal and emergency lighting, as well as for light appliances and equipment is supplied at 120 volts through suitable transformer step-down. Nominal supply voltage is 115 volts. The emergency power system can supply power for interior communication, battery charging, electronic, navigation and related emergency equipment. The general alarm and power alarm panel are battery supplied.

The distribution system includes three dead front, metal enclosed cubical type switchboards to control the three generators. The master switchboard includes one generator control panel, one synchronizing panel, two bus tie panels and a distribution panel. The second panel is of similar configuration but omits the synchronizing panel and utilizes only one bus tie panel. The third panel, which serves as the emergency switchboard, consists of a generator control panel, a bus tie panel, and a distribution panel.

Each drive unit and their generators are mounted on common bed plates. The drive for the standby generator is taken by a special clutching arrangement from one of the diesel engines normally used to drive a lift fan.

4.5.4 Electrical System Weight Breakdown

The weight breakdown of the electrical system is included in Table 4-xvi.

TABLE 4-xvi
WEIGHT OF ELECTRICAL SYSTEM SWBS GROUP 300

SWBS NUMBER	ITEM	WEIGHT LT
311	Ship Service Power Generator	38.8
313	Battery and Service Facility	1.0
314	Power Conversion Equipment	1.0
321	Ship Service Power Cable	12.0
324	Switch Gear and Panels	21.0
331	Lighting Distribution	9.0
332	Lighting Fixtures	6.5
343	Diesel and Turbine Support Systems	4.5
398	Electrical Plant Operating Fluids	1.0
399	Electrical Plant Repair Parts	0.3
300	TOTAL Electrical Plant	95.1

4.5.5 Electrical System Risk Assessment

All electrical system components are currently available from marine suppliers and in general utilize procedures and installation proven in other applications. In addition, equipment of similar configuration in slightly smaller and larger capacities are readily available; therefore, no technical risk or special development is anticipated for this area.

4.6 NAVIGATION, CONTROL AND COMMUNICATION (NCC) SYSTEM

The NCC System consists of the Navigation and Collision Avoidance System (NAV-CAS), and the Exterior and Interior Communication System. The Ship Control System (SCS) is treated as a special independent element of the Interior Communication System.

4.6.1 NCC System Description

The SCS includes those elements required for control of course, speed, and maneuvering in a seaway, as well as a means for controlling and monitoring the ship plants. Ease of operation and maintenance is assured through an

intermediate level of control integration. The NAVCAS provides the capability for worldwide navigation and generates continuous absolute and relative position fixes, as well as ship's speed, heading, and attitude data. The navigation subsystem includes the hardware and processing equipment necessary to receive and utilize signals from Loran and satellite radio navigation. Two radars, one main S-band and one auxiliary X-band, provide the capability to sense and quantitatively measure potential collision situations. The collision avoidance subsystem displays the surface situation and computes trial evasive maneuvers so the ship may more easily avoid potential areas of danger.

4.6.2 System Characteristics

The NCC System provides a moderate level of integration. The bridge control console includes a navigation section where all associated navigation aids and communication elements are consolidated. The Engineering Station or central machinery control and performance monitor allow control and performance evaluation of machinery elements. Separate subsets of the machinery control and performance monitoring area are provided for propulsion, lift, electrical plant, auxiliary subsystems, and damage control. The propulsion plant responds automatically to either the bridge or Engineering Station throttle command.

The Interior Communication System which includes the alarm systems and the SCS, which in turn includes:

a. Sound power telephone

b. Automatic dial telephone

c. Shore side telephone outlets

d. Public address system

e. Loudspeaker system

f. Salinity indicator system

g. Tank level indicator

h. Equipment monitor.

The SCS in addition provides the means for initiation and control of ship maneuvers from the central bridge station and for plant monitoring and control for the Engineering Station.

The NAVCAS include an electronic position fixing system echo depth sounders, and radar-collision avoidance system. The electronic position fixing consists of a Loran C and satellite navigation system with processor and heavy duty teleprinter. The radar system includes both a main S-band radar and an auxiliary X-band radar. Either radar can be connected to a collision avoidance system by electronic interswitching. This system provides unattended monitoring of radar echo and visual and audible alarms to alert the crew of possible threats and provides features to enhance collision avoidance.

The MPS is equipped with a comprehensive exterior communication package as detailed in Table 4-xvii. All systems, elements and components required to provide a satisfactory navigation, control and communication system are available and no technical risk is anticipated for this area.

EXTERIOR COMMUNICATION SUITE

EQUIPMENT
Radio Transmitting/Transceiver Facilities
o HF
o VHP
o MF
Radio Receiving Facilities
o HF
o LF/MF
Terminal System
o VV SC Simplex AFT/RFCS RATT non-secure
Secure Voice Terminal
o VHF SC Secure Voice (narrow band)
Special Systems
o Converter - Comparator (CV-3510/VG)
o Sitor Error Correction Device
o Digital Selective Caller
o 500 KHz Alarm Receiver
o Auto Alarm Keyer

TABLE 4-xvii

4.6.3 NCC System Weight Breakdown

The weights of major NCC subsystems are listed in Table 4-xviii.

WEIGHT OF NAVIGATION CONTROL AND COMMUNICATION SYSTEMS SWBS GROUP 400

SWBS NUMBER	ITEM	WEIGHT LT
421	Non-Electrical/Electronic Navigation Aids	0.1
422	Electrical Navigation Aids	1.2
423	Electronic Navigation System, Radio	0.3
424	Electronic Navigation System, Depth	0.2
426	Electronic Navigation System	0.5
432	Telephone System	1.5
433	Announcing System	2.4
434	Entertainment System	0.8
438	Integrated Control System	14.0
441	Radio Communication	1.3
443	Visual and Audible System	0.1
451	Surface Search Radars, two	0.5
400	Total Command and Surveillance	22.9

TABLE 4-xviii

4.7 AUXILIARY SYSTEMS

4.7.1 Auxiliary Systems Description

The auxiliary systems consist of the machinery, piping, and ducting required to support other ship systems. They include, as well as normal ship hotel services, fluid distribution, fire extinguishing, underway replenishment and mechanical handling for anchors, mooring and towing.

4.7.2 Auxiliary Systems Arrangement

The majority of the auxiliary machinery is located in the sidewalls on the machinery flats between bulkheads 317 and 282. Within these auxiliary machinery rooms (AMRs) are fitted such major functional equipment as the fuel distribution manifold and pumping system, distilling plants, sea water pumps, sewage disposal system, and air conditioning machinery. However, the refrigeration units are not in either AMR, but situated adjacent to the freezer and reefer storerooms that they serve on the main deck.

4.7.3 Auxiliary Systems Characteristics

Significant features of the auxiliary system are described briefly in the following subparagraphs.

4.7.3.1 Climate Control Systems

The climate control systems consist of the compartment heating, ventilation and air conditioning (HVAC); cargo space ventilation; and machinery space ventilation and heating.

The major ventilation demand is the required air change for the cargo stowage spaces when used for transportation of gasoline-powered vehicles. The MARAD Specification for this requirement has been followed and results in the following needs:

a. Cargo (motor vehicles) embarked - 12 air changes per hour.

b. RO/RO - 30 air changes per hour.

Initial calculations of cargo space show a volume of 2,450,000 ft^3. A total fan capacity of 6800 cfs during transit and 20,400 cfs during loading and unloading operations is required to achieve the necessary air change which is accomplished by utilizing the 6 x 6000 cfs capacity main lift fans. The alternative, numerous smaller fan units placed longitudinally along the upper side hulls, would significantly increase the weight, maintenance, electrical load and ducting requirements.

All cabins, mess decks, recreation rooms, dining rooms, offices, commissary, medical, control, and electronics spaces are air conditioned. Two 450V 60Hz electric motor-driven 25 ton direct expansion plants are fitted in the AMRs for this purpose, though use of certain self-contained units where the location of a compartment makes this more practicable will be considered later.

Machinery space ventilation for the main propulsion, generating and auxiliary machinery rooms is provided by a total of four supply and four exhaust fans each of 15,000 cfm capacity.

4.7.3.2 Seawater Systems

The combined seawater systems (machinery cooling and firemain) is provided by six 500 gpm, 150 psi pumps, three in each sidewall. Each has its own sea chest and pump riser leading to a common horizontal ring main on 2 deck from which branches lead to the superstructure, upper deck and lower decks as required for fire plugs and water eductors. Two cross-connections are fitted between the port and starboard legs of the ring main adjacent to frames 200 and 480 immediately below the main deck. Cooling water for heat exchangers and auxiliary machinery is taken from the pump risers at the machinery flat level, pressure reducing valves as appropriate being fitted for compatible equipment pressures. Seawater discharges are combined where practical and directed overboard.

The largest design commitment for the firemain is to cope with a possible fire on the gasoline powered vehicle cargo decks. Aqueous Film Forming Foam (AFFF) proportionater tanks are fitted at the deck head of these compartments and feed fixed foam sprinkling systems. Groups of sprinklers can be individually selected,

each group having a "blanketing capacity" of about 1200 ft^2 and sized for a minimum flow of 200 gallons/minute. In addition to the foam sprinkling system, foam hose outlets are located so that any point on the cargo decks can be reached by at least two outlets.

4.7.3.3 Fresh Water Systems

The fresh water production system and stowage was sized for a 38 man crew and passenger carrying capability of 50. In addition, there is a requirement for main propulsion gas turbine fresh water wash down. Two 2500 gallons per day electrically heated vapor compression distilling plants are fitted. Stowage of 3600 gallons of fresh water is provided for domestic use and a further 500 gallon tank is available for the gas turbines. One potable water pump is fitted for water circulation, and hot water is provided by electric immersion heaters.

4.7.3.4 Fuels and Lubricants Systems

The fuel system provides control of the fuel distribution in the ship's storage tanks, together with purification of and delivery to the fuel consuming machinery. The ship's fuel system consists of two electrically-driven main fuel pumps with filter coalescer systems for processing fuel taken from the storage tanks and transferred to the clean fuel oil service tanks. Fuel taken from service tanks is delivered to the combustion service of each engine by an engine-dedicated delivery pump.

The main fuel pumps are used for fuel distribution between storage tanks for trim control purposes. Fuel flow bypasses the filter coalescer element when the pumps are functioning in this mode.

Contaminated discharge from the filter coalescer system is delivered to waste fuel drain tanks for subsequent discharge overboard or to a disposal service facility. An oil and water separator ensures that condensate of seepage water discharged overhead satisfies environmental protection requirements. A stripping system is provided with service to all fuel tank spaces.

There are dedicated lubrication systems for:

a. Each main gas turbine

b. Each diesel engine

c. Emergency generator gas turbine and gearbox

d. Each pair of propulsion reduction gear and propeller shaft bearing sets

e. Each set of lift fans.

Oil cooling is provided by heat exchangers with cooling water supplied from the seawater system.

4.7.3.5 Air, Gas and Miscellaneous Fluids

The air, gas, and miscellaneous fluid systems consist of low pressure compressed air high pressure compressed air, fire extinguishing and hydraulic fluid systems. The ship's service air system is provided by an electrically driven 125 psi air compressor, which has its own associated filter, dehydrator, and accumulator elements. Distribution is provided to each cargo deck, machinery space and the workshop.

Two 600 psi motor driven high pressure (HP) air compressors, fitted one each in the port and starboard AMRs, feed HP air storage bottles adjacent to each diesel that require 426 psi air for starting. Starting air for the main propulsion gas turbines is provided by two auxiliary power units situated one each in the port and starboard main propulsion machinery spaces.

Fixed flooding Halon systems are the primary fire extinguishing systems for the propulsion, lift, electrical and auxiliary machinery rooms. Halon gas bottles sufficient to supply a 6 to 7 percent concentration by volume for individual spaces are provided. Halon extinguishing is also provided for each gas turbine compartment.

Two motor driven hydraulic pumps deliver nominal 3000 psi hydraulic power to a ship service hydraulic loop. Principle hydraulic users are the vehicle ramps, sliding doors, boat davits, and winches.

4.7.3.6 Underway Replenishment System

No provision is made for stores to be transferred at sea other than by VERTREP. The upper deck is not structurally designed for helicopter operations. Fueling at sea can be undertaken on either port or starboard side where standard eight inch probe receivers are fitted. The system is designed to accept 3000 gpm of fuel from the transfer ship.

4.7.3.7 Mechanical Handling Systems

Mechanical handling systems comprise anchor handling, mooring and towing, and requirements for small boat handling.

The American Bureau of Shipping criterion was used to determine anchor sizes and cable requirements. The high freeboard and therefore large wind area of the MPS results in the need for three 13,200 pound stockless bower anchors, one of which is spare. In-use anchors are stowed in hawse recesses in the upper area of the port and starboard sidehulls. The anchoring system utilizes 2-3/8 inch steel chain cable and a total of 315 fathoms is carried.

Two electro-hydraulic anchor capstans are fitted for anchoring and mooring operations. Winches, fair leads and bitts facilitate wire handling when securing to a pier. No provision is made for this ship to tow another, but fair leads and bitts, together with towing bridles, are located forward should towing of the MPS be necessary.

To comply with the Code of Federal Regulations, boatage to accommodate all persons and associated hydraulically operated boat handling system is provided both port and starboard side. Additionally, there are four 25-person life rafts in standard containers on the main deck.

4.7.3.8 Steering Systems

The ship is steered from the Pilot House by the Mate on watch. A dual electric system, port and starboard, provides the signal to two hydraulic pumps which are sited aft, one in each sidehull. The pumps which are driven by a continuous rated electric motor control two rudders through a conventional feed back system.

For emergency operation, a secondary steering position for each rudder is provided at the hydraulic pumps; orders for steering angle being passed by sound powered telephone from the Pilot House.

Steering also can be augmented by differential thrust accomplished through propeller pitch differences or by propulsive power control.

4.7.3.9 Pollution Control System

Pollution control features are incorporated. Soil and waste drains collected by the plumbing drainage system and held in Collecting, Holding and Transfer Tanks (CHT) are either transferred to a shore sewage facility, or discharged overboard outside contiguous zone when the ship is off-cushion. Food wastes are ground in a garbage grinder and directed to the CHT system, which has a capacity sufficient for one day's wastes. Each tank contains an air aspirator system that prevents the contents from becoming anaerobic (with resulting obnoxious fumes). Solid wastes are compacted and stored for disposal at a shore facility.

4.7.3.10 Auxiliary System Weight Breakdown

The weight breakdown of the auxiliary subsystems is presented in Table 4-xix.

4.7.3.11 Auxiliary System Risk Assessment

All auxiliary system components are well within the present state-of-the-art; therefore, no technical risk or development program is envisaged.

4.8 OUTFIT AND FURNISHINGS

4.8.1 Summary Description

Outfit and furnishings include material, equipment, and furnishing not included elsewhere in the Ship Work Breakdown Structure, but necessary to provide human support and complete the functional use of spaces and areas. For purpose of brevity only major areas are indicated:

a. Ship Fittings

b. Hull Compartmentation

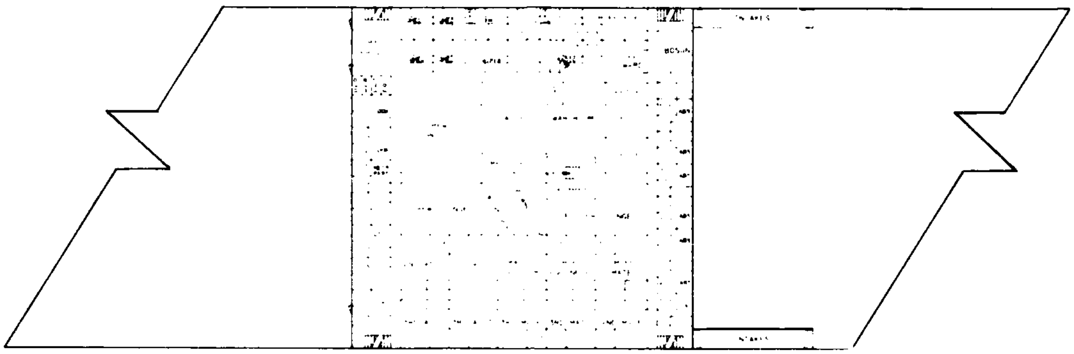
c. Preservatives and Coatings

d. Spaces-Living, service, working, and storage.

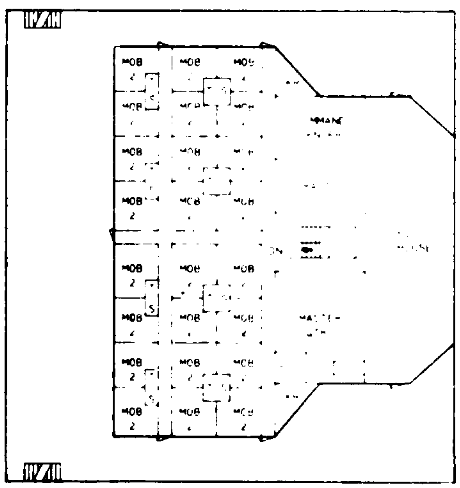
4.8.2 Outfit and Furnishings Arrangements

Figure 4-34 shows plan layouts for the crew, passengers and mobilization living spaces and Figure 6.1-4 for engineering compartment arrangements on the sixth deck. Care was taken to place all living quarters and ship control functions on

01 LEVEL AND MAIN DECK HOUSE



MAIN DECK HOUSE
75' ABL



01 LEVEL
85' ABL

BHD 105' 8"

SYMBOL	DEFINITION
ABS	ABLE BODY SEAMAN
ASST	ASSISTANT
FRZ	FREEZER
LKR	LOCKER
MOB	MOBILIZATION CREW
OS	ORDINARY SEA PERSON
QMED	QUALIFIED MEMBERS OF ENGR DEPT
RADIO OP	RADIO OPERATOR
REF	REFRIGERATOR
SK	STORE KEEPER
T S	TOILET & SHOWER
T	TOILET
UTIL	UTILITY PERSON
EM	ENGINE MECHANIC
PAN	PANTRY
SCLY	SCULLERY
ELEC	ELECTRICIAN

FIGURE 4–34

the main deck. The volume aft of the engine air intakes is used for ladders leading to the cargo and engineering spaces below, thus minimizing interference with cargo flow. To this end, functional spaces have been co-located with storage spaces.

Workshops are located in either sidehull on the machinery deck between bulkheads 317'-00" and 422'-08" where there is ample room for storage of repair parts and flammable liquids.

WEIGHT OF AUXILIARY SYSTEMS SWBS GROUP 500

SWBS GROUP	ITEM	WEIGHT LT
511	Compartment Heating	0.75
512	Ventilation (Cargo Holds)	1.50
513	Machinery Space Ventilation	10.00
514	Air Conditioning	12.00
516	Refrigeration System	1.00
521	Seawater & Firemain	34.50
522	Sprinkler System	2.00
526	Scuppers & Deck Drains	5.00
528	Plumbing Drainage	1.00
529	Drainage & Ballasting	7.00
531	Distilling Plant	3.00
532	Cooling Water	1.25
534	Drains within Machinery Box	1.00
541	Fuel & Fuel Compartment System	10.00
551	Compressed Air System	8.00
555	Fire Extinguishing System	25.00
556	Hydraulic Fluid System	3.00
561	Steering	16.00
571	Replenishment at Sea	1.00
581	Anchor Handling & Stowage	50.00
582	Mooring & Towing System	10.00
583	Boat Handling & Stowage	20.00
584	Ramps & W/T Doors	40.00
593	Environment Pollution Control	3.00
	TOTAL Auxiliary Systems	266.00

TABLE 4-xix

WEIGHT OF OUTFIT AND FURNISHINGS SWBS GROUP 600

GROUP	TITLE	WEIGHT LBS	LT
611	Hull Fittings	11,200	5.0
612	Rails, Stanchions	11,200	5.0
613	Rigging & Canvas	2,240	1.0
621	Nonstruct Bulkheads	6,720	3.0
622	Floor Plates, Gratings	8,960	4.0
623	Ladders	11,200	5.0
624	Nonstruct Closures	4,480	2.0
625	Airports, Windows	2,240	1.0
631	Painting	44,800	20.0
633	Cathodic Protection	11,200	5.0
634	Deck Covering	22,400	10.0
635	Insulation	412,160	184.0
637	Sheathing	2,000	0.9
641	Master's Berth & Mess	15,520	6.9
642	Mate's Berth & Mess	2,000	0.9
643	EM Berth & Mess	21,825	9.7
644	Sanitary Space, Fixtures	2,985	1.3
645	Leisure & Community	3,960	1.8
651	Commissary	9,315	4.2
652	Medical	1,865	0.8
654	Utility	0	0
655	Laundry	500	0.2
661	Offices	1,850	0.8
662	Bulletin Boards	150	0.1
663	Pilot House	3,895	1.7
665	Workshops	9,500	4.2
671-672	Lockers/Stores	26,885	12.0
698	Operating Fluids	4,480	2.0
699	Repair Parts	1,000	0.5
	TOTAL Outfit & Furnishings	656,530	293.0

TABLE 4-xx

4.8.3 Outfitting and Furnishings Weight

A volume estimate of 3KSES spaces (SWBS 640-690) listed in the 3KSES Weight Summary was used to determine an equivalent specific weight (lbs/ft^3). Weights for the MPS were derived once the volume of appropriate spaces was determined. This results in an estimate of 293.0 LT for the 600 Weight Group, as shown in Table 4-xx.

4.9 DESIGN WEIGHT

The following design weight report for the MPS utilizes the format of the Naval Ship Systems Command Ship Work Breakdown Structure (NAVSHIPS 0900-039-9010) to the element level. All reported equipment weights have been obtained from either manufacture's published data or detailed analysis of the 3KSES design data package. Structural weights have been estimated from preliminary structural drawing and loads analysis.

4.9.1 Weight Summary

SWBS GROUP	DESCRIPTION	WEIGHT (LT)
100	Structure	3,917
200	Propulsion	255
300	Electric	95
400	Communication & Surveillance	23
500	Auxiliary	266
567	Lift System	284
600	Outfit & Furnishings	293
700	Armament	None
Design & Builders Margin		255
LIGHT SHIP		5,388
F	Loads	
F10	Personnel	5
F30	Provision-Personnel Stores - General	8
F40	Lube, Hydraulic Oil	14
F50	Fresh Water	13
TOTAL - Ready for Sea		5,428
F60	Cargo	5,950
	Tie Downs	313
TOTAL Cargo		6,262
	Fuel	3,309
TOTAL (FLD)		15,000

Note: Removable decks may be stored ashore when not required.

4.9.2 Structure - SWBS Group 100

SWBS GROUP	DESCRIPTION	WEIGHT (LT)
110*	Shell & Support Structure	1,750.7
120*	Hull Structure Transverse Bulkheads	108.3
130*	Hull Decks	1,536.2
140*	Hull Machinery Flats & Platform	193.4
150	Deck House Structure (Aluminum)	95.5
160*	Special Structures (HY-100 Steel)	62.0
	(Aluminum)	62.2
170	Masts, King Post & Service Platform (Aluminum)	9.0
180	Foundations (Aluminum)	99.7
TOTAL		3,917.0

*Constructed from HY100 Steel

4.9.3 Propulsion Plant - SWBS Group 200

SWBS GROUP	DESCRIPTION	WEIGHT (LT)
234	Propulsion Turbines	23
241	Reduction Gearing	120
242	Clutches & Couplings	4
243	Shafting	13
244	Bearings	12
245	Propellers	30
251	Combustion Air System	24
252	Propulsion Control	1
259	Exhaust System	15
261	Fuel Service	1
262	Lube Oil Service	7
298	Operating Fluids	4
299	Repair Parts	1
TOTAL		255

4.9.4 Electrical System - SWBS Group 300

SWBS GROUP	DESCRIPTION	WEIGHT (LT)
311	Ship Service Power Generator	38.8
313	Battery & Service Power Generator	1.0
314	Power Conversion Equipment	1.0
321	Ship Service Power Cable	12.0
324	Switch Gear & Panels	21.0
331	Lighting Distribution	9.0
332	Lighting Fixtures	6.5
343	Diesel Support Systems	4.5
398	Electrical Plant Operating Fluids	1.0
399	Electrical Plant Repair Parts	0.3
TOTAL		95.1

4.9.5 Navigation, Control and Communication Systems - SWBS Group 400

SWBS GROUP	DESCRIPTION	WEIGHT (LT)
421	Non-Electrical/Electronic Navigation Aids	0.1
422	Electrical Navigation Aids	1.2
423	Electronic Navigation System, Radio	0.3
424	Electronic Navigation System, Depth	0.2
426	Electronic Navigation System	0.5
432	Telephone System	1.5
433	Announcing System	2.4
434	Entertainment System	0.8
438	Integrated Control System	14.0
441	Radio Communication	1.3
443	Visual & Audible System	0.1
451	Surface Search Radars, Two	0.5
TOTAL		22.9

4.9.6 Auxiliary Systems - SWBS Group 500

SWBS GROUP	DESCRIPTION	WEIGHT (LT)
511	Compartment Heating	0.75
512	Ventilation (Cargo Holds)	1.50
513	Machinery Space Ventilation	10.00
514	Air Conditioning	12.00
516	Refrigeration System	1.00
521	Seawater & Firemain	34.50
522	Sprinkler System	2.00
526	Scuppers & Deck Drains	5.00
528	Plumbing Drainage	1.00
529	Drainage & Ballasting	7.00
531	Distilling Plant	3.00
532	Cooling Water	1.25
534	Drains within Machinery Box	1.00
541	Fuel & Fuel Compartment System	10.00
551	Compressed Air System	8.00
555	Fire Extinguishing System	25.00
556	Hydraulic Fluid System	3.00
561	Steering	16.00
571	Replenishment At Sea	1.00
581	Anchor Handling & Stowage	50.00
582	Mooring & Towing System	10.00
583	Boat Handling & Stowage	20.00
584	Ramps & W/T Doors	40.00
593	Environment Pollution Control	3.00
TOTAL		266.00

4.9.7 Lift System - SWBS Group 567

SWBS GROUP	DESCRIPTION	WEIGHT (LT)
	Fan System Subbase (6)	22.26
	Demister	1.24
	Exhaust	.45
	Sound Attenuation	.19
	Shafting	1.79
	Fans (6 DWDI)	35.36
	Weather Inlets	7.91
	Air Distribution Ducts	4.46
	Air Valves, Distribution Ducts	2.04
	Vent System	2.23
	Fuel Oil Connect	.05
	Lube Tanks	1.23
	Engine Controls	.09
	Lube Oil Pumps for Fans	1.79
	Shaft Brakes & Torque Meter	.17
	Electrical Connector	.01
		81.27
	6 SACM 240-V20-RVR Diesel Engines with GB and All Accessories	162.00
	Bow Seal	22.5
	Stern Seal	18.5
TOTAL		284.00

4.9.8 Outfit & Furnishings - SWBS Group 600

SWBS GROUP	DESCRIPTION	WEIGHT (LT)
611	Hull Fittings	5.0
612	Rails, Stanchions	5.0
613	Rigging & Canvas	1.0
621	Nonstruct Bulkheads	3.0
622	Floor Plates, Gratings	4.0
623	Ladders	5.0
624	Nonstruct Closures	2.0
625	Airports, Windows	1.0
631	Painting	20.0
633	Cathodic Protection	5.0
634	Deck Covering	10.0
635	Insulation	184.0
637	Sheathing	0.9
641	Master's Berth & Mess	6.9
642	Mate's Berth & Mess	0.9
643	EM Berth & Mess	9.7
644	Sanitary Space, Fixtures	1.3
645	Leisure & Community	1.8
651	Commissary	4.2
652	Medical	0.8
654	Utility	0.0
655	Laundry	0.2

4.9.8 Outfit & Furnishings - SWBS Group 600 (cont'd)

SWBS GROUP	DESCRIPTION	WEIGHT (LT)
661	Offices	0.8
662	Bulletin Boards	0.1
663	Pilot House	1.7
665	Workshops	4.2
671-672	Lockers/Stores	12.0
698	Operating Fluids	2.0
699	Repair Parts	0.5
TOTAL		293.0

4.9.9 Bow Seal Weight Estimate

	COMPONENT		WEIGHT (LBS)
BAG			
	Lobe Panels (180 oz/yd^2)		7,970
	Straps (170 oz/yd^2)		500
	End Caps (180 oz/yd^2)		3,010
	Clamping Bead Inserts		400
	Apron (180 oz/yd^2)		480
	Apron/Finger Attachment Hardware (Steel)		640
		BAG	13,000
FINGERS			
	Set of ten (10) (170 oz/yd^2) (Based on four seams)		28,500
	Clamping Bead Inserts		200
		FINGERS	28,700
ATTACHMENT CLAMPS			
	Bag-to-Hull (Steel)		5,670
	Finger-to-Hull (Steel)		4,000
		ATTACHMENTS	9,670
TOTAL			51,370

4.9.10 Stern Seal Weight Estimate

COMPONENT		WEIGHT (LBS)
BAG (Multi-Lobe)		
	Lobe Panels (180 oz/yd^2)	6,645
	End Caps (180 oz/yd^2) (Toroidal & Conical Sections)	8,355
	Straps (170 oz/yd^2)	250
	Horizontal Web (170 oz/yd^2)	4,370
	Vertical Web (170 oz/yd^2) (Set of Five)	6,750
	Planing Panel (180 oz/yd^2)	7,700
	Fiberglass Sheathing 1/16" thick	270
	BAG	34,340
ATTACHMENT CLAMPS		
	Clamping Bead Inserts	400
	Internal Clamping Hardware (Steel)	1,100
	Bag-to-Hull (Steel)	5,700
	ATTACHMENT	7,200
TOTAL		41,540

4.9.11 Variable Loads Weight Estimate

Allowance Per Man

PERSONNEL	WEIGHT (LBS)
Officers (Licensed)	400
CPOs (Senior Non-Licensed)	330
Enlisted (Non-Licensed)	230

Weight Allowances (Crew and Effects)

PERSONNEL	QTY	WEIGHT (LBS)
Licensed	11	4,400
Senior (Non-Licensed)	3	990
Non-Licensed	24	5,520
	38	10,910 = 4.87 LT

Weight Allocation for Provisions, Personal Stores, and General Stores

PROVISIONS	POUNDS PER MAN PER DAY
Dry	3.20
Freeze	1.11
Chill	1.65
Clothing & Small Stores	.07
Ship's Store	.08
General Stores	1.06
	7.89

4.9.12 Weight Estimate Of Cargo Handling Systems

Type of System (Dimensions)(Material)	Quantity	SWBS 160 Unit Weight LT	SWBS 160 Total Weight LT	SWBS 584 Unit Weight LT	SWBS 584 Total Weight LT
Fixed Interior Deck Ramp (20' x 54') (Aluminum)	2	8.6	17.2	-	-
Movable Hinged Deck Ramp (20' x 54') (Aluminum)	2	11.67	23.3	1.5	3.0
Exterior Watertight Door/Ramp (22' x 14') (HY-100)	4	5.1	20.4	2.9	11.6
Exterior Watertight Door/Ramp (16' x 14') (HY-100)	5	3.7	18.5	2.1	10.5
Exterior Door/Ramp Extension (21' x 13') (HY-100)	4	3.03	12.1	1.2	4.8
Exterior Door/Ramp Extension (15' x 13') (HY-100)	5	2.2	11.0	0.9	4.5
Interior Watertight Door (16' x 14') (Aluminum)	10	2.17	21.7	0.6	16.8
Subtotal			124.2		40.4
Removable 3rd Deck* (48,000 sq. ft.) (Aluminum)	1	171	171	-	-
Removable 4th Deck** (43,105 sq. ft.) (Aluminum)	1	188	188	-	-
			483.2		

*Removable 3rd Deck is used for the Airborne Division only and included as part of the payload weight.

**Portions of 4th Deck are removable and included as part of the payload weight.

5. MANNING AND HABITABILITY

5.1 MANNING CONCEPT

Two operational profiles were considered in the development of the MPS manning concept. Primary consideration was given to manning for Military Sealift Command (MSC) operational control with Navy Civil Service and Navy military personnel. This concept supports a mission profile of providing strategic mobility support and service for the Army, Navy, Marine Corps, and Air Force in war and emergency or contingency.

A nominal 38-person crew complement for the ship under MSC operational control is projected. The second concept projected requirements for full civilian personnel manning to support commercial application of the MPS. A nominal 28-person crew complement resulted. A comparison of manning requirements between the preliminary design requirements, the Maritime Administration requirements for the PD-214 (a proposed RO/RO ship), and this study's projected requirements is depicted in Table 5-i. Dependent upon the degree of automation contemplated for the MPS, the manning level could be further reduced.

The operational/maintenance manning objective is directed toward reduced manning. Table 5-ii provides the projected manpower utilization. Watch station requirements are combined by utilization of automated equipment. Additionally, personnel would not be assigned for the sole purpose of performing maintenance. The ship system design will incorporate provisions for installing condition monitoring equipment in mission essential systems to eliminate or minimize preventive maintenance requirements and thereby reduce personnel requirements. Operational and corrective maintenance actions performed by the ship's crew will be directed toward maintaining equipment in an operational state by utilization of a component and module replacement strategy. The impact of reduced manning on the variable load weight is shown in Table 5-iii. Ship systems will be designed to permit incremental overhaul of subsystems and related auxiliaries. Major maintenance actions and non-essential equipment and components maintenance will be deferred for in-port availabilities and for support by functional maintenance activites.

5.2 HABITABILITY

General habitability arrangements, based on Navy requirements and information provided by the Military Sealift Command, are shown in Figure 4-34. In view of the desire to maximize the cargo load, stowage and offload capabilities, all accommodations were placed in a side-to-side superstructure at the main deck level. This location resulted from the dual need to accommodate access to lifeboat embarkation stations, frames 90-130 port/starboard, to engine room spaces, and to accommodate both the gas turbine intakes and the various machinery exhaust systems. The galley, crew mess, supporting reefer and associated spaces are located

COMPARATIVE MANNING REQUIREMENTS
OF CONVENTIONAL AND SES MULTI-PURPOSE SHIPS

	Billet	PDR[1]	PD-214[2] Standard	PD-214 Gas Turbine	MPS Civilian	MPS MSC
1.	Master	1	1	1	1	1
	DECK DEPARTMENT					
2.	Chief Mate	1	1	1	1	1
3.	2ND Mate	0	0	0	1	1
4.	3RD Mate	1	1	1	1	1
5.	3RD Mate	1	1	1	0	1
6.	Radio Officer	0	1	1	1	1(USN)
7.	Bosun	1	1	1	1	1
8.	AB Seaperson	1	1	1	1	1
9.	AB	1	1	1	1	1
10.	AB	1	1	1	1	1
11.	AB	1	1	1	1	1
12.	AB	1	1	1	1	1
13.	AB	1	1	1	1	1
14.	OS Seaperson	1	1	1	1	1
15.	OS	1	1	1	1	1
16.	OS	1	1	1	1	1
17.	Radio Operator	1	0	0	0	1(USN)
18.	Radio Operator (USN)	0	0	0	0	1(USN)
	ENGINEERING DEPARTMENT					
19.	Chief Engineer	1	1	1	1	1
20.	1ST Assistant	1	1	1	1	1
21.	2ND Assistant	1	1	1	1	1
22.	3RD Assistant	1	1	1	1	1
23.	3RD Assistant	1	1	0	0	1
24.	Chief Electrician	1	1	1	1	1
25.	Engine Mechanic	1	1	0	0	1
26.	QMED	1	1	1	1	1
27.	QMED	1	1	1	1	1
28.	QMED	1	1	1	1	1
29.	QMED	1	1	1	0	1
30.	Wiper	1	1	1	1	1
31.	Storekeeper (USN)	0	0	0	0	1(USN)
	STEWARDS DEPARTMENT					
32.	Chief Steward	1	1	1	1	1
33.	Chief Cook	1	1	1	0	1
34.	Cook	1	1	1	1	1
35.	Utility Person	1	1	1	1	1
36.	Utility Person	1	1	1	0	1
37.	Utility Person	1	1	1	0	1
38.	Mess Person	1	1	1	1	1
	TOTAL	34	34	32	28	38

[1] PDR - Preliminary Design Requirements Estimate

[2] PD-214 - Maritime Administration Proposed Ship Type

TABLE 5-1

PROJECTED MANPOWER UTILIZATION

	BILLET	AT SEA STEAMING	ENTER/DEPART PORT	ENGINEERING CASUALTY	FIRE EMERGENCY
1.	Master	In Command	Bridge-in Command	In Command	Bridge-in Command
DECK DEPARTMENT					
2.	Chief Mate	Ship Control	Bridge-SC Officer	Bridge and AR	At Scene-in Charge
3.	2ND Mate	Ship Control-Watch	Forecastle-in Charge	As Required	Bridge-SC Officer
4.	3RD Mate	Ship Control-Watch	Stern-in Charge	As Required	Life Boat in Charge
5.	3RD Mate	Ship Control-Watch	Midships-in Charge	As Required	As Required
6.	Radio Officer	Radio-in Charge	Radio-in Charge	Radio-in Charge	Radio-in Charge
7.	Bosun	Day Maint/Cargo	Forecastle Lines	As Required	At scene-Emerg Squad
8.	AB Seaperson	Quartermaster	Forecastle-Lines	As Required	Emerg Squad-Provided
9.	AB	Quartermaster	Forecastle-Lines	As Required	Emerg Squad-Provided
10.	AB	Quartermaster	Midships-Lines	As Required	Emerg Squad-Provided
11.	AB	Lookout	Midships-Lines	As Required	Emerg Squad-Provided
12.	AB	Lookout	Stern-Lines	As Required	Boat Station
13.	AB	Lookout	Stern-Lines	As Required	Boat Station
14.	Ordinary Seaperson	Maint-Housekeeping	Forecastle-Lines	As Required	Emerg Squad-Messenger
15.	OS	Cargo	Midships-Lines	As Required	Bridge-Messenger
16.	OS	Cargo	Stern-Lines	As Required	Emerg Squad-Messenger
17.	Radio Operator	Radio Watch	Radio-Watch	As Required	Boat Station
18.	Radio Operator	Radio Watch	As Required	As Required	As Required
ENGINE DEPARTMENT					
19.	Chief Engineer	In Charge of Dept.	In Charge of Dept.	At Scene	In Charge Eng. Dept.
20.	1ST Assistant	Engine Console	Engine Console	Off-Watch	Engine Console
21.	2ND Assistant	Engine Console	Asst. at Console	As Required	Asst. at Console
22.	3RD Assistant	Engine Console	Machinery-TBD	As Required	Asst. Chief Engr
23.	3RD Assistant	Asst. at Console	Machinery-TBD	As Required	Asst. Chief Engr
24.	Chief Electrician	Asst. at Console	Machinery-TBD	Repair Team	Machinery
25.	Engine Mechanic	Asst. at Console	Machinery-TBD	Repair Team	Space as Directed
26.	QMED	Asst. Chief Engr.	Machinery-TBD	Repair Team	Emergency Squad
27.	QMED	Roving Patrol/Monitor	Machinery-TBD	Repair Team	Emergency Squad
28.	QMED	Roving Patrol/Monitor	Machinery-TBD	Repair Team	Emergency Squad
29.	QMED	Roving Patrol/Monitor	Machinery-TBD	Repair Team	Emergency Squad
30.	Wiper	Housekeeping	Machinery-TBD	Repair Team	Emergency Squad
31.	Storekeeper	Spares Storeroom	As Required	As Required	Emergency Squad
STEWARD'S DEPARTMENT					
32.	Chief Steward	In Charge of Dept.	In Charge of Dept.	In Charge of Dept.	In Charge of Dept.
33.	Chief Cook	Food Prep.	Normal Duties	Normal Duties	Secure Galley
34.	Cook	Food Prep.	Normal Duties	Normal Duties	Secure Galley
35.	Utility Person	Food Service	Normal Duties	Normal Duties	Secure Salon
36.	Utility Person	Food Service	Normal Duties	Normal Duties	Secure Staterooms
37.	Utility Person	Food Service	Normal Duties	Normal Duties	Secure Staterooms
38.	Mess Person	Food Service/Clean-Up	Normal Duties	Normal Duties	Secure Staterooms

TABLE 5–ii

VARIABLE LOADS WEIGHT ESTIMATE

In accordance with Naval Ships Technical Manual 1 Mar 1974, Chapter 9290 Para. 173.1

Personnel	Pounds Per Man
Officers (Licensed)	400
CPOs (Senior Non-Licensed)	330
Enlisted (Non-Licensed)	230

Weight Allowances (Crew and Effects)

Personnel	QTY	Weight
Licensed	11	4,400
Senior Non-Licensed	3	990
Non-Licensed	24	5,520
	38	10,910 LB = 4.87 LT

Weight Allocation for Provisions, Personal Stores, and General Stores

Provisions	Pounds Per Man Per Day
Dry	3.20
Freeze	1.11
Chill	1.65
Clothing & Small Stores	.07
Ship's Store	.08
General Stores	1.06
	7.89

For 30-Day Mission:

38 Men x 30 Days x 7.89 LBS/MAN/DAY = 8994.60 LBS

= 4.02 LT

TABLE 5-iii

near the centerline of the main deck house. This central location provides the required separation of the unlicensed (enlisted) accommodations to the port side of the main deck house and the licensed (officer) accommodations to starboard. Four ladder-ways provide access to the main cargo and engineering spaces, while at the same time minimizing the loss of usable cargo space. Boat stowage and embarkation have not been assigned, but it is anticipated the main deck level aft of the deck house structure (port and starboard) will be utilized.

Accommodations for the master and mobilization/passenger personnel are located on the 01 Level aft of the pilot house. The pilot house, radio room, and navigation support areas are on the centerline at the 01 Level. Each area is served by a central ladder-way terminating on the main deck level within the deck house. Although depriving the conning officer of a deck edge location which is highly desirable in docking situations, the centerline control station is of primary importance with regard to the orientation of the conning officer, while underway in the high relative motion situations caused by the MPS's inherent speed capability. The central location and height of the pilot house are ideally suited for control when underway, especially during high speed operation. Provisions will be made on the port and starboard wings of the 01 Level for two maneuvering stations equipped with direct communications to the pilot house and engine and steering control indicators. These stations will be used during maneuvers in port and in and out of docks.

Although USCG Regulations for Cargo Vessels, 46 CFR 92.15-15 and 92.20-50, contain general provisions for adequacy of quarters ventilation and heating, the advent of modern air conditioning and heating systems and pressures for improved crew habitability generated by maritime labor unions have largely overtaken these regulations. The installation of packaged conditioned air systems, produced by recognized manufacturers, is generally accepted as meeting the requirements cited in the foregoing regulations and will be considered during detail design. There are at present no specific regulations for noise level control on board commercial vessels. The Coast Guard has, however, recently sponsored tests at the Naval Ocean Systems Center (NOSC), San Diego, CA, which addressed the question of current noise levels aboard merchant vessels and proposed recommendations for acceptable shipboard noise levels. This undertaking indicates that considerations of shipboard noise levels are being addressed within the regulatory community. Considering the multiplication of high frequency noise sources, such as those produced by a gas turbine, noise regulation is a valid concern and will be considered during the detail design.

Specific requirements for lighting both inside and outside the accommodations spaces are set forth in the Subchapter J Electrical Regulations of the USCG. Regular and emergency lighting requirements are addressed, as well as requirements for special spaces such as the MPS cargo areas.

There are no specific Coast Guard Requirements for fresh water systems

other than compliance with specified requirements of the U.S. Public Health Service with regard to isolation of potable water tanks from salt water, fuel oil and other shipboard sources of contamination. There are no requirements as to amounts carried; however, distilling plants utilizing pressure vessels are subject to applicable portions of the Marine Engineering Regulations, Subchapter F. U.S. Public Health Regulations with regard to ratproofing sanitary aspects of the food service areas are also applicable.

46 CFR 92.20 details the requirements for officer and crew accommodations. Once again, union requirements generally mandate accommodations that far exceed the requirements of these regulations. Deck area and volume allocations of the Coast Guard Regulations are met by this design. Semi-private sanitary facilities provided for each stateroom far exceed Coast Guard requirements. 46 CFR 92.20-40 sets forth general requirements for lounge, welfare, recreation, and personnel service spaces and facilities that are usually dictated by management-labor agreements.

6. PAYLOAD INTEGRATION AND LOGISTICS

6.1 PAYLOAD INTERFACE TRADE STUDY

Compatibility between the stowage and handling requirements of the payload and various options available in the selection of primary ship proportions and design features were considered. The analysis consisted of the following major elements:

a. Description of cargo characteristics in terms of weight, deck area, vertical height, and handling requirements.

b. Evaluation of ship proportion options.

c. Evaluation of cargo access and handling systems with respect to weight, space, and cargo handling time.

d. Payload stowage analysis.

e. Preliminary time line analysis for loading and offloading.

6.1.1 Payload Description

6.1.1.1 Military Payload

Two types of military cargo were considered: (1) Equipments of a United States Army Airborne Division, and (2) Equipments of a United States Army Armored Division.

Tables 6-i and 6-ii describe shipping configuration weights, deck areas and heights of the equipments that comprise an Airborne Division and an Armored Division, respectively. The Army divisions exclude combat support and combat service units which vary in type and quantity according to mission needs. Nominal allowances for the weight of tie-down equipment and the access required for vehicle maneuvering and personnel operations are included. Five percent of the total payload weight is used for the weight of tie-down equipment. Twenty-five percent of the total payload deck area represents the access area needed for vehicle maneuvering and personnel operations.

Liaison with U.S. Army agencies, including the Transportation Engineering Agency located in Newport News, Virginia, provided identification of equipment by line number on the U.S. Army Forces Command (FORSCOM) Computerized Movement Planning and Status System (COMPASS) Consolidated Cargo Listing printed 31 January 1980 for the 2nd Armored Division, Fort Hood, Texas, and the 82nd Airborne Division, Fort Bragg, North Carolina.

AIRBORNE DIVISION PAYLOAD SHIPPING CONFIGURATIONS

EQUIPMENT (TOE Line Item Number)	QUANTITY	LENGTH (FT)	WIDTH (FT)	HEIGHT (FT)	UNIT WEIGHT (LT)	UNIT AREA (SQ FT)	TOTAL VALUES WEIGHT (LT)	TOTAL VALUES AREA (SQ FT)
TRUCK, 5 ton, cargo (X40968)	44	26.6	8.2	7.2	9.7	218.1	426.8	9,596
TRUCK, 2 1/2 ton, cargo (X40146)	270	23.2	8.0	6.7	6.1	185.6	1,647.0	50,112
TRUCK, 1 1/4 ton, cargo (X39940)	694	19.3	7.1	5.6	3.3	137.0	2,290.2	95,078
TRUCK, 1/4 ton, utility (X60833)	801	11.0	5.3	4.4	1.1	58.3	881.1	46,698
HELICOPTER, attack (K29660)	48	45.3	7.2	12.5	2.3	326.2	110.4	15,658
HELICOPTER, utility (K31795)	93	42.7	8.5	13.0	2.2	363.0	204.6	33,759
HELICOPTER, observation (K31042)	74	32.0	6.8	9.6	0.8	217.6	59.2	16,102
CARRIER, command personnel (D11538)	3	16.0	8.3	8.7	10.0	132.8	30.0	398
						GRAND TOTAL (NET)	5,649.3	267,401
						TIEDOWNS (5% WEIGHT) & ACCESS (25% AREA)	282.5	66,850
TOTAL QUANTITY	2,027					GRAND TOTAL (GROSS)	5,931.8	334,251

TABLE 6-1

ARMORED DIVISION PAYLOAD SHIPPING CONFIGURATIONS

EQUIPMENT (TOE Line Item Number)	QUANTITY	LENGTH (FT)	WIDTH (FT)	HEIGHT (FT)	UNIT WEIGHT (LT)	UNIT AREA (SQ FT)	TOTAL VALUES WEIGHT (LT)	TOTAL VALUES AREA (SQ FT)
TANK, combat, M60A1 (V13101)	324	26.9	11.9	10.8	43.3	320.1	14,029.2	103,712
TRUCK, 8 ton, cargo (X41653)	132	31.8	9.1	8.2	11.2	289.4	1,478.4	38,201
TRUCK, 5 ton, cargo (X40968)	35	26.6	8.2	7.2	9.7	218.1	339.5	7,634
TRUCK, 2 1/2 ton, cargo (X40146)	652	23.2	8.0	6.7	6.1	185.6	3,977.2	121,011
TRUCK, 1 1/4 ton, cargo (X39940)	339	19.3	7.1	5.6	3.3	137.0	1,118.7	46,443
TRUCK, 1/4 ton, utility (X60833)	769	11.0	5.3	4.4	1.1	58.3	845.9	44,833
HELICOPTER, attack (K29660)	9	45.3	7.2	12.5	2.3	326.2	20.7	2,936
HELICOPTER, utility (K31795)	22	42.7	8.5	13.0	2.2	363.0	48.4	7,986
HELICOPTER, observation (K31042)	42	32.0	6.8	9.6	0.8	217.6	33.6	9,139
CARRIER, personnel (D12087)	577	16.0	8.3	7.0	8.9	132.8	5,135.3	76,626
CARRIER, command personnel (D11538)	130	16.0	8.3	8.7	10.0	132.8	1,300.0	17,264
HOWITZER, medium (K57667)	54	29.6	10.4	9.2	21.8	307.8	1,177.2	16,621
HOWITZER, heavy (K56981)	12	29.6	10.3	9.0	26.8	304.9	321.6	3,659
				GRAND TOTAL (NET)			29,825.7	469,065
		TIEDOWNS (5% WEIGHT) & ACCESS (25% AREA)					1,491.3	124,016
TOTAL QUANTITY 3,097				GRAND TOTAL (GROSS)			31,317.0	620,081

TABLE 6-ii

6.1.1.2 Commercial Payload

The ship is capable of carrying various types of commercial rolling stock, break-bulk and containers. Two types of commercial containerized cargo were considered: (1) 40-foot containers (40 ft. x 8 ft. x 8 ft.), and (2) 20-foot containers (20 ft. x 8 ft. x 8 ft.). Normal loaded weights of these containers are 15 LT each for 40-foot containers and 11 LT each for 20-foot containers.

6.1.2 Ship Proportion Options

This section details ship design factors and ship proportion options considered in the determination of primary ship proportions.

6.1.2.1 Ship Design Factors

Ship design factors that were influential in establishing primary ship proportions included the following:

a. Payload weight and volume

b. Maximum ship displacement of 15,000 LT

c. Unrefueled range of at least 3,900 nm at 15,000 LT displacement

d. Minimum ship speed of 33 kt at 15,000 LT displacement

e. Minimum number of ships to deliver payload

6.1.2.2 Assessment of Ship Proportion Options

Airborne and Armored Division military cargos were considered the primary payloads. Commercial RO/RO and containerized cargo were treated as secondary payloads. Ship proportion options were optimized for handling Airborne and Armored divisions cargo in the same ship.

First, ship proportions were optimized for stowage of the Armored Division. Analysis of the cargo established the need for five ships to satisfy cargo weight requirements. The transportation of the Armored Division cargo is therefore bound by cargo weight capacity limitations of the ship.

Second, ship proportions were selected for stowage of the Airborne Division. Analyses of the cargo deck area requirements indicated that cargo for the Airborne Division was volume critical and that two ships with four decks would be required. The cargo weight analysis established that weight of the Airborne Division cargo was not a limiting factor for this type of cargo.

From these iterations it was decided to optimize the ship proportions for stowage of the Airborne Division. This satisfied area and volume

requirements of both Airborne and Armored Division cargos and minimized the number of ships required. At the same time the full load displacement was optimized for the heavier Armored Division cargo. To maximize ship loading fexibility between the volume limited airborne cargo and weight limited armored cargo, two of the interior decks are portable and are only installed as needed.

6.1.3 Access and Handling Systems

The cargo functions of loading, stowage, and offloading were evaluated as a series of transportation links. Experience with previous Roll On/Roll Off (RO/RO) designs (i.e., Comet and Challenger) and the objective of minimization of weight influenced the selection of optimum cargo access and handling systems.

Determination of the optimum cargo handling systems was an iterative process consisting of the following steps:

a. Evaluation of cargo handling systems

b. Evaluation of cargo ingresses/egresses

c. Evaluation of weight estimates for cargo handling systems

6.1.3.1 Cargo Handling Systems

The basic cargo handling functions are loading, internal stowage and offloading. Analysis of available loading/unloading systems resulted in the retention of the following alternatives for detailed evaluation:

a. RO/RO with ramps

b. RO/RO with deck edge elevators

c. Lift-On/Lift-Off (LO/LO) from deck, elevators or platforms by cranes

d. Fly-On/Fly-Off (FO/FO) for helicopters and/or cargo

A cargo loading/offloading system matrix was developed from the detailed evaluation to summarize and compare the relative efficiency of each system. Matrix element numbers indicate the relative order of ranking with the lower number the most desirable.

CARGO LOADING/OFFLOADING SYSTEM MATRIX

System	Load/Offload Time	Weight Efficiency	Area Efficiency
RO/RO (Ramps)	1	1 (fixed or hinged ramps)	2*
RO/RO (deck edge elevators)	2	3* (4 elevators)	3
LO/LO	3	3* (12 deck edge platforms)	1
FO/FO	4	2 (2 elevators)	2*

* Difference not considered significant for this study.

Appendix B provides the initial assumptions and preliminary calculations concerning load/offload time of each cargo handling system. The RO/RO concept with ramps provides minimum load/offload time of 4.6 hours, while load/offload time for the RO/RO concept with deck edge elevators is 9.5 hours. Load/offload time of LO/LO is 30.6 hours (due to constraints of pier facility crane operations) and load/offload time of FO/FO is excessive due to fly-off preparation of helicopters.

The weight and area efficiencies of ramps and elevators were based upon estimates contained in earlier SES study reports. The area efficiency of the LO/LO concept with deck edge platforms is the highest as this concept utilizes the least amount of cargo deck area. The area efficiency of ramps and elevators is approximately equal.

RO/RO operation cycle times required for vehicle handling, were superior to the LO/LO cycle times as demonstrated by the Comet-Challenger tests in 1963 ("Three Winning Designs - FDL, LHA, DD-963: Method and Selected Features", R. Leopold and W. Reuter, The Society of Naval Architects and Marine Engineers Transactions, Volume 79, 1971, pg. 329). The limitations of a RO/RO concept for helicopter handling were defined and feasibility of such an operation established. Calculations in Appendix B indicate that the towing of helicopters on wheeled cradles is feasible provided minimal access ramp angles (less than 5 degrees) are maintained and no abrupt changes in elevation exist.

The RO/RO handling system with ramps was selected for handling military and commercial cargo due to its superiority in load/offload time and weight efficiency. Additionally, the RO/RO concept was selected for handling commercial containers on the 5th deck in conjunction with the LO/LO concept for handling containers on the 1st (main) deck. The LO/LO concept proved optimum due to the efficiency of crane operations in container port facilities.

Fixed ramps, hinged ramps and elevators were compared for their effectiveness in handling cargo. Results of the comparative analysis are shown below:

INTERNAL HANDLING METHOD MATRIX

Method	Cargo Handling Efficiency	Weight Efficiency	Cargo Area Efficiency	Reliability
Fixed Ramps	1*	1	*	1
Hinged Ramps	1*	2	*	2
Elevators	2	3	*	3

* Difference not considered significant for this study.

Note: Matrix element numbers indicate relative ranking with the lowest number the most desirable.

The cargo handling efficiency of ramps in terms of load/offload time is higher than elevators as discussed earlier. Fixed ramps have the highest weight efficiency due to the lack of machinery components required by hinged ramps and elevators. The cargo area efficiency of ramps and elevators is approximately equal. Fixed ramps, by design, provide the optimum reliability.

Fixed ramps were used (when feasible) as a result of their high efficiencies in cargo handling time and their advantages in terms of weight, cargo area, and reliability. Ramps hinged at the fourth deck were necessary to facilitate helicopter loading and storage. Ramp designs were based on cargo characteristics and angles of existing shipboard ramps as shown in Table 6-iii. The USNS Comet fixed ramp angle of 17 degrees was used as the maximum ramp design angle, after consideration

EXISTING SHIPBOARD RAMPS

TYPE OF SHIP	SHIP NAME OR CLASS	RAMP ANGLE (DEG) FIXED	RAMP ANGLE (DEG) HINGED	RAMP WIDTH (FT) FIXED	RAMP WIDTH (FT) HINGED	REMARKS
Naval Amphibious Ships	LHA-1	14.5	14.5	20	12	
	LST 1156	12	18	entire width of well	15	
	LPD-4	23	23		10	
	LSD-28	16.5	NA	10	NA	
Military Sealift Cargo Ships	USNS Comet (C3-ST-14a)	17	16	10	10	S Shaped Ramps
	USNS Callaghan	14	NA	16	NA	
Commercial Ships	Matsonia (Sun Shipbuilding RO/RO)	10	NA	18	NA	S Shaped
	Maine (C7-S-95a)	7.5	NA	24	NA	

NA = Not Applicable

TABLE 6-iii

of the geometry of the RO/RO cargo and the weight impact of shallower ramp angles.

6.1.3.2 Selection of Cargo Ingresses/Egresses

Initial design effort attempted to provide as many ingress/egress points as possible, assuming that cargo flow in or out of the ship would be orifice-limited. However, selection of the RO/RO handling system eliminated requirements for weather deck egress points and analysis of cargo stowage and internal flow allowed further reduction of egress points to two port, two starboard, and five stern egresses. These ingress/egress locations provide the MPS with sufficient flexibility to optimize cargo loading/off-loading.

6.1.3.3 Weight Estimates of Cargo Handling Systems

General arrangement drawings of the MPS, Figures 6-1, 6-2, 6-3 and 6-4 were used to estimate the weight of the cargo handling systems. Material weights are based on the use of aluminum or HY100 steel. Table 6-iv lists the estimated weights for the cargo handling systems.

Exterior access ports are hydraulically operated watertight doors; 14 feet high and 16 feet wide at the stern, and 22 feet wide at the sides. Each door serves as a ramp with a sliding ramp extension 13 feet long and 15 feet wide for stern doors and 21 feet wide for side doors. The sliding ramp is secured to the watertight door when in the closed position. No external crane service is necessary for placement or stowage.

Hydraulically operated interior watertight doors are of two types: a sliding or hinged swing, dependent upon clearance and cargo stowage requirements.

Interior fixed ramps between decks are 20 feet wide to allow for personnel access and two lane traffic on the ramps. A removable 3rd deck (car deck) is used for the Airborne Division and small commercial vehicles. The car deck ramp is a 10 foot wide hinged section of a larger fixed ramp. Several sections of the 4th deck are also removable.

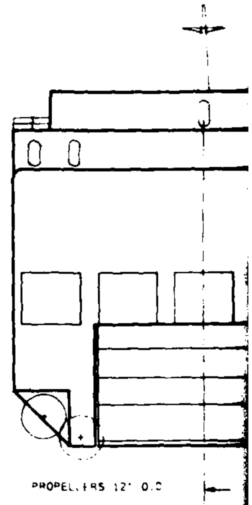
The watertight movable (hinged) ramps between the 4th and 5th decks are 20 feet wide and are hydraulically operated.

Fixed ramps are designed for 8 ton cargo trucks weighing 11.2 tons each, and movable ramps are designed for tanks weighing 43.3 tons each. Structural restraints require the 54 foot main girders of the fixed ramps to have column supports approximately 26 feet on center. The hinged ramps also have supports at approximately the 26 foot point.

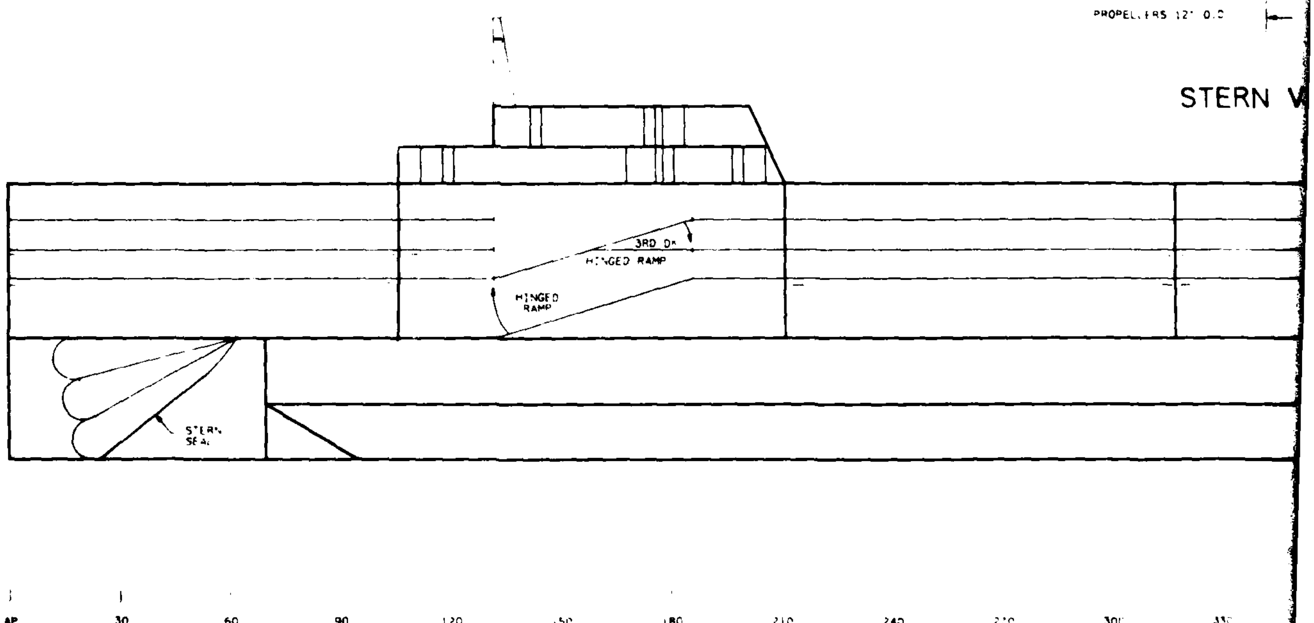
6.1.4 Payload Stowage Analysis

Stowage analysis consisted of the following steps:

INBOARD CENTERLINE PRO



STERN V



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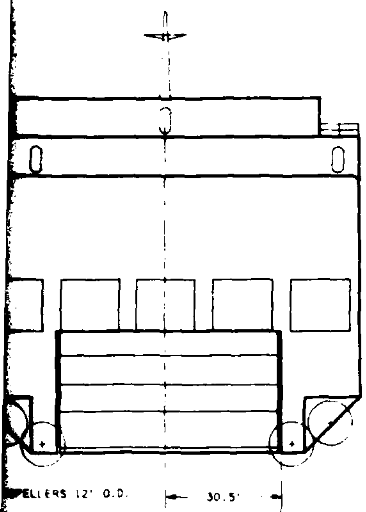
TERLINE PROFILE & STERN VIEW



STERN VIEW

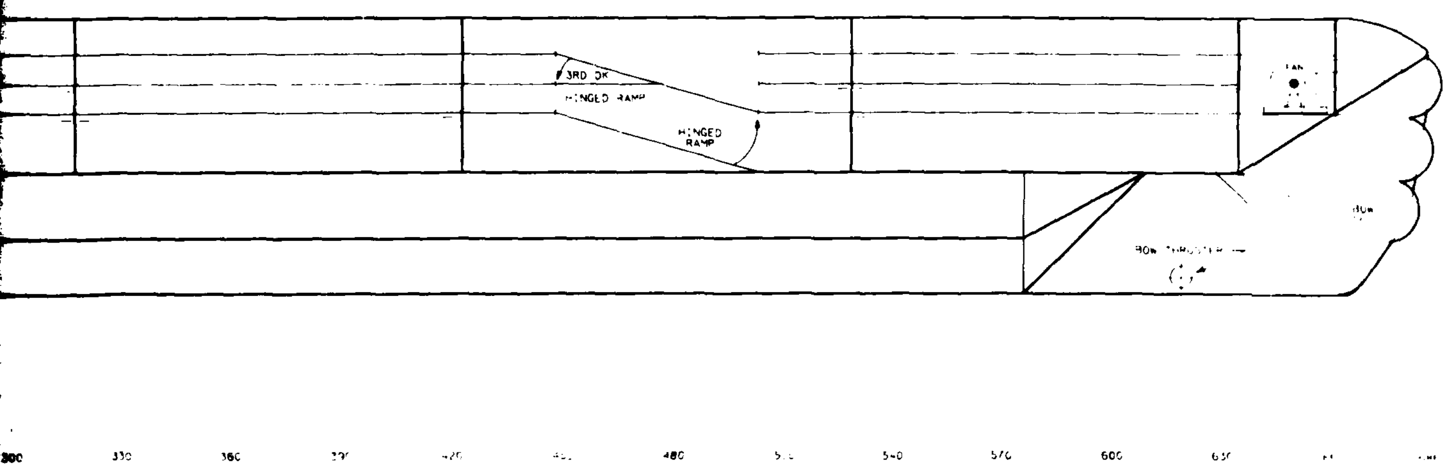
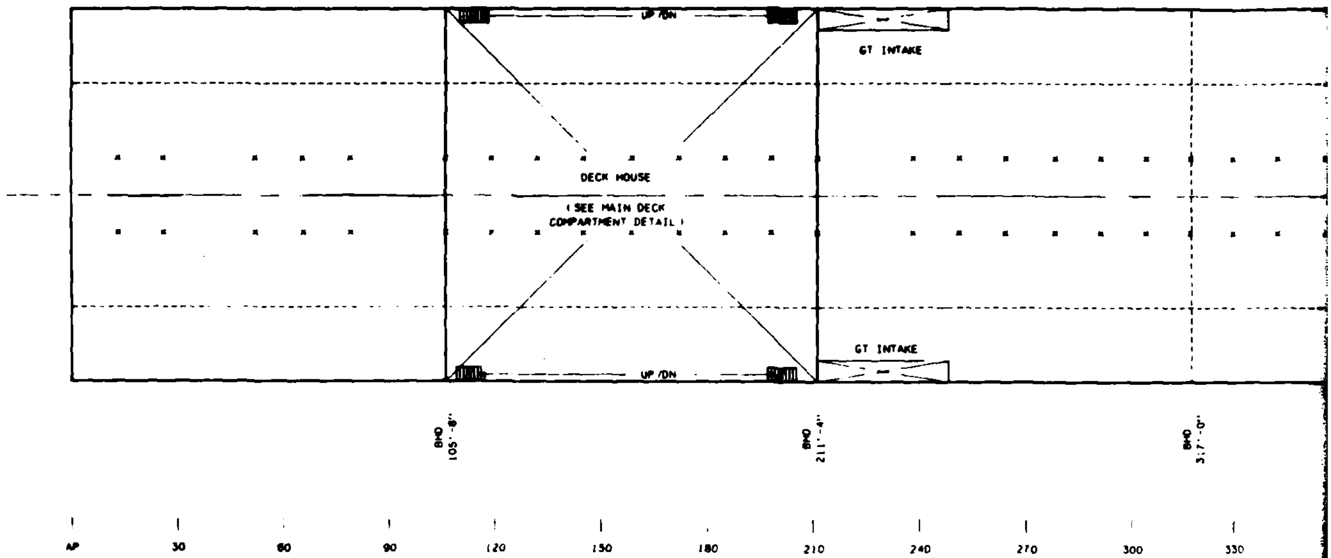
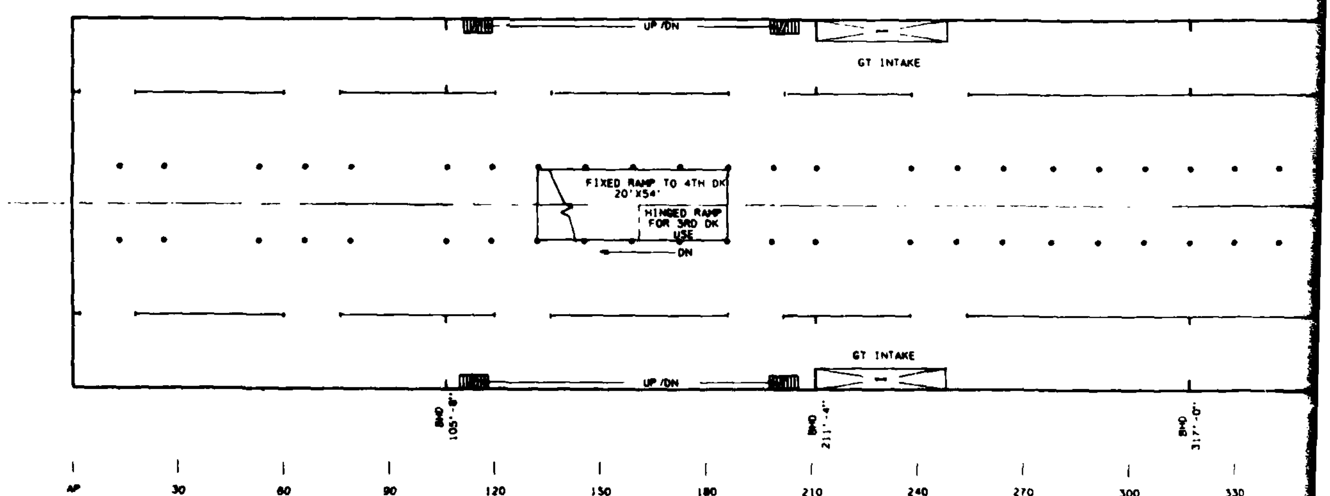


FIGURE 6–1

MAIN AND SECOND DE

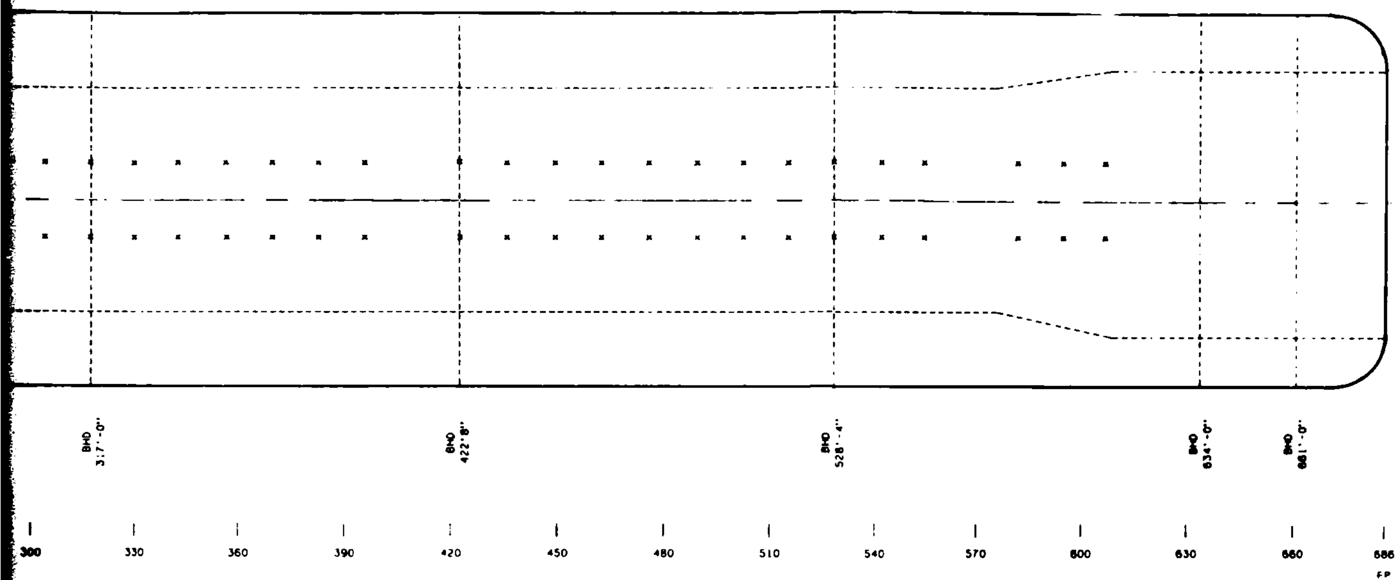


1ST DECK (MAIN DECK)
75' ABL



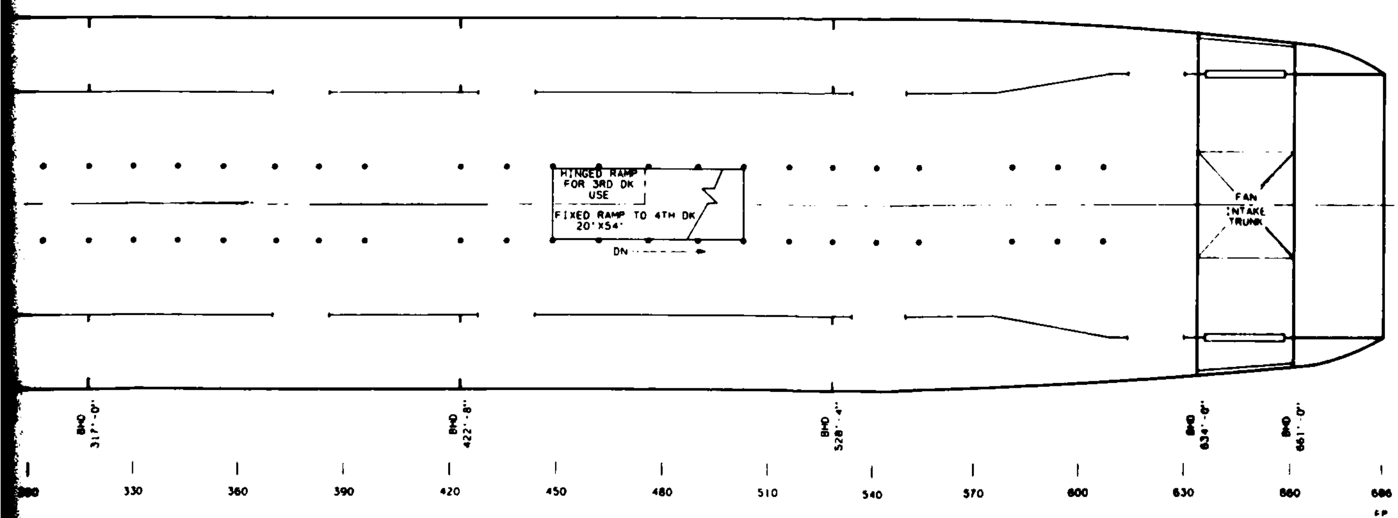
2ND DECK
65' ABL

ND SECOND DECKS



ECK (MAIN DECK)
75' ABL

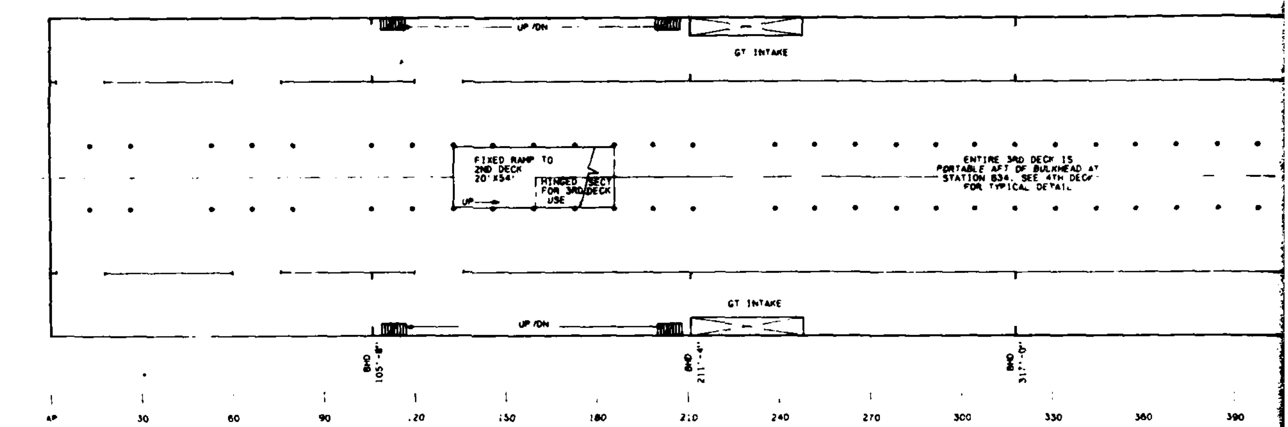
NOTE: (X) INDICATES STANCHION BELOW MAIN DECK.



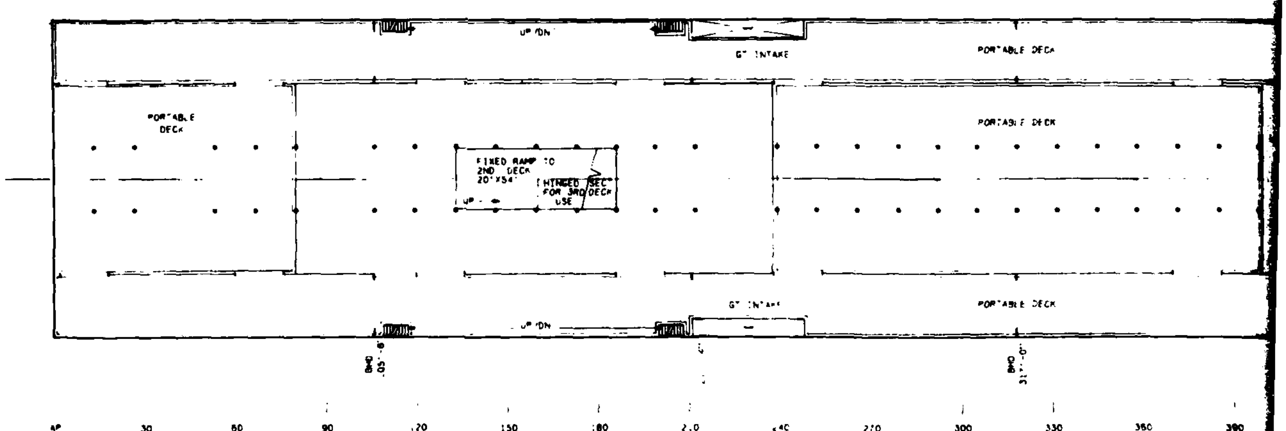
2ND DECK
65' ABL

FIGURE 6–2

THIRD AND FOURTH DE

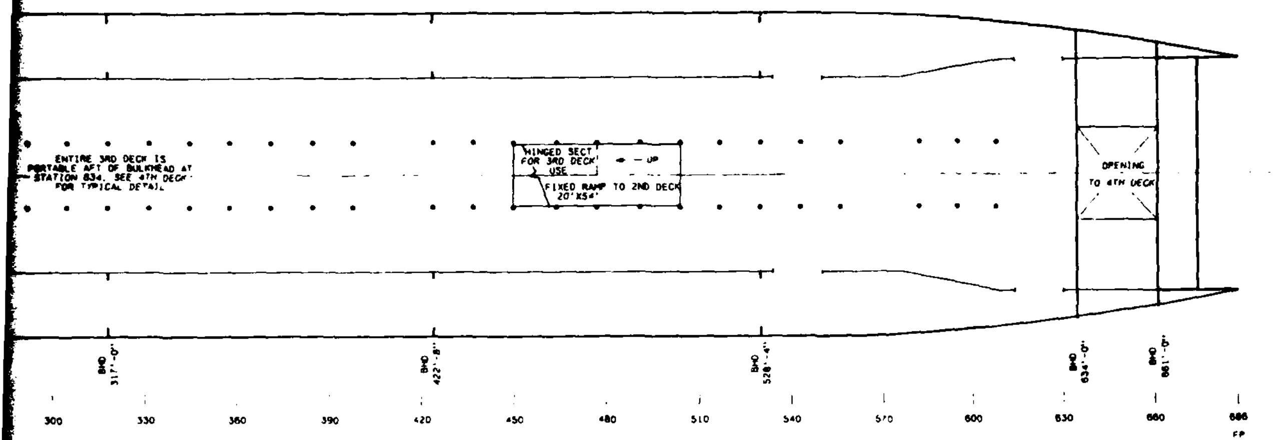


3RD DECK (CAR DECK)
58' ABL

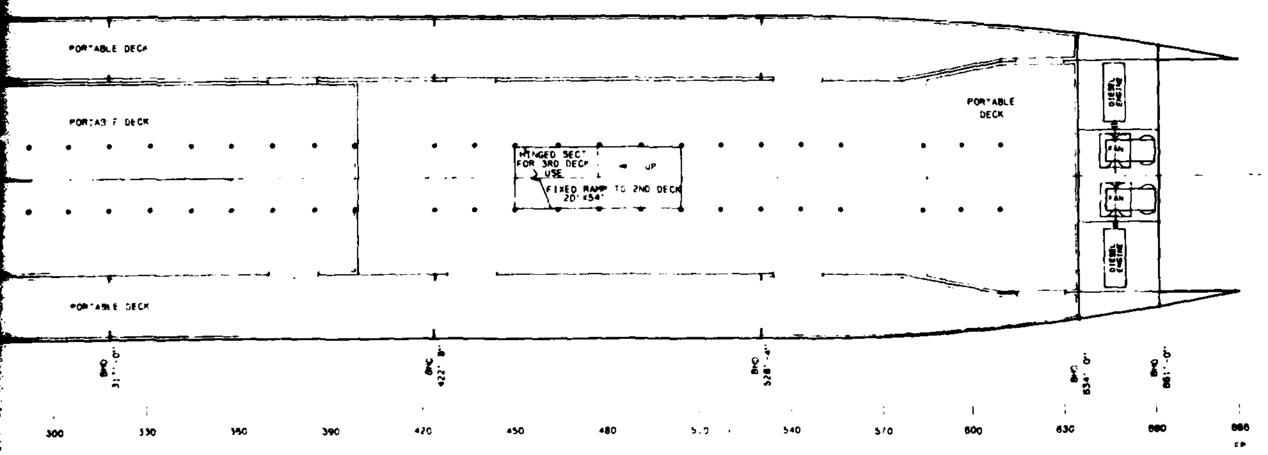


4TH DECK
49' ABL

THIRD AND FOURTH DECKS



D DECK (CAR DECK)
58' ABL

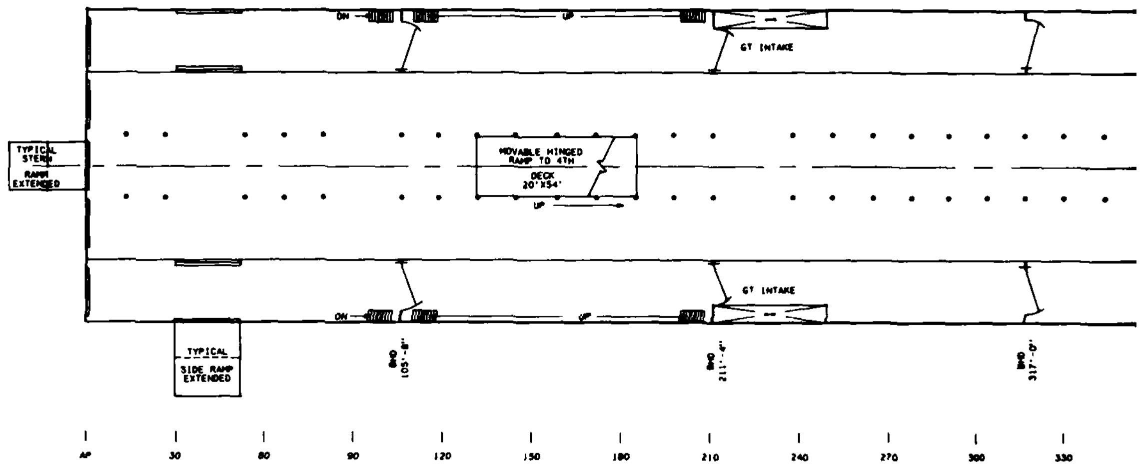


4TH DECK
49' ABL

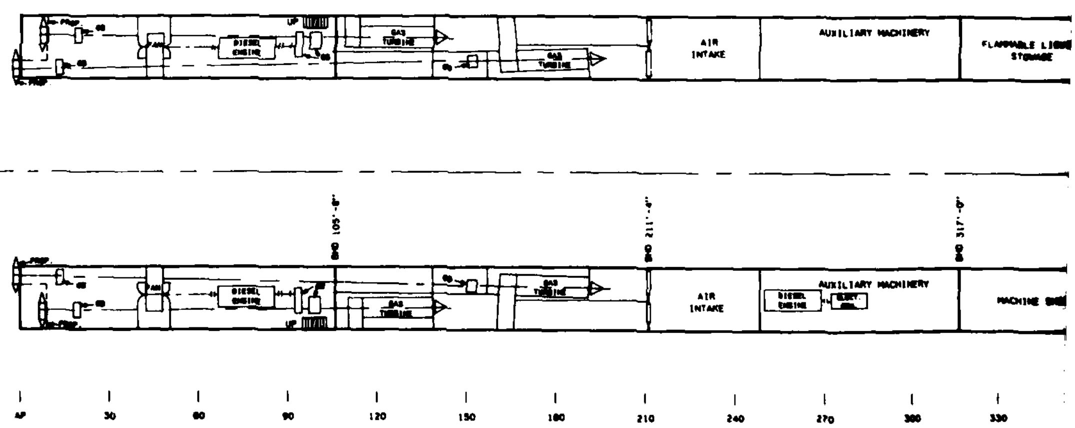
FIGURE 6–3

2

FIFTH AND SIXTH D

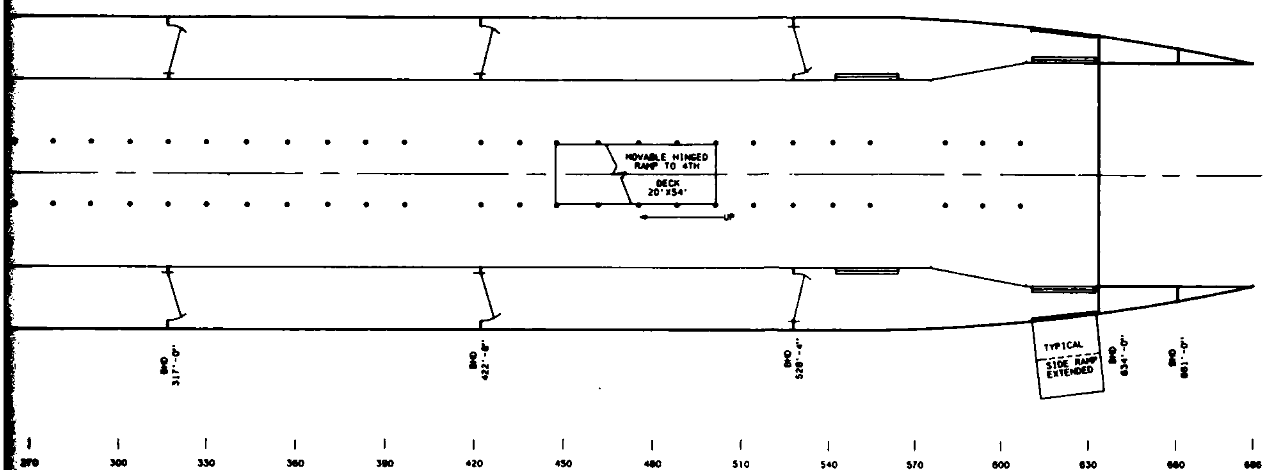


5TH DECK (TANK DECK
33' ABL

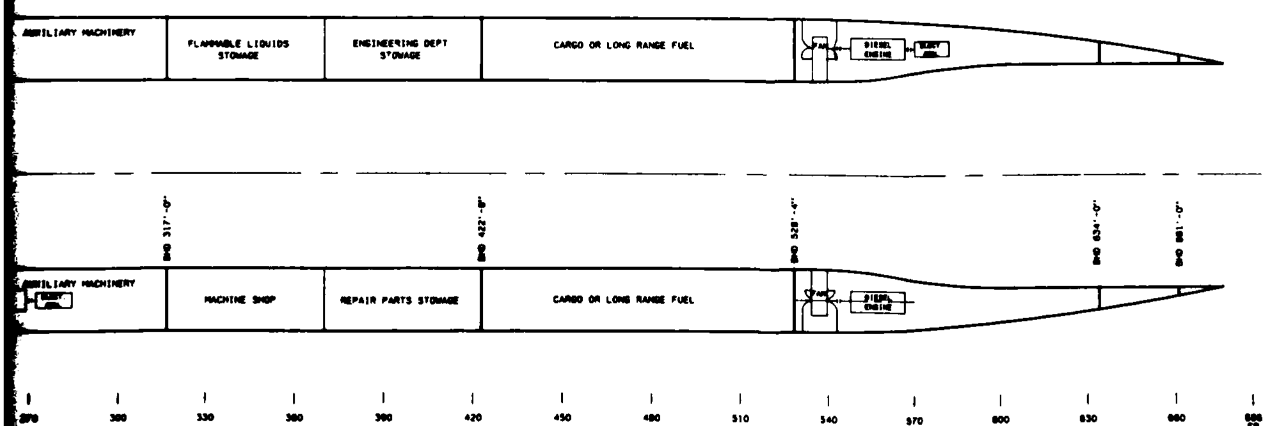


6TH DECK
MACHINERY FLAT
15' ABL

FIFTH AND SIXTH DECKS



5TH DECK (TANK DECK)
33' ABL



6TH DECK
MACHINERY FLAT
15' ABL

FIGURE 6–4

WEIGHT ESTIMATE OF CARGO HANDLING SYSTEMS

Type of System (Dimensions)(Material)	Quantity	SWBS 160 Unit Weight LT	SWBS 160 Total Weight LT	SWBS 584 Unit Weight LT	SWBS 584 Total Weight LT
Fixed Interior Deck Ramp (20' x 54') (Al)	2	8.6	17.2	-	-
Movable Hinged Deck Ramp (20' x 54') (Al)	2	11.67	23.3	1.5	3.0
Exterior Watertight Door/Ramp (22' x 14') (HY-100)	4	5.1	20.4	2.9	11.6
Exterior Watertight Door/Ramp (16' x 14') (HY-100)	5	3.7	18.5	2.1	10.5
Exterior Door/Ramp Extension (21' x 13') (HY-100)	4	3.03	12.1	1.2	4.8
Exterior Door/Ramp Extension (15' x 13') (HY-100)	5	2.2	11.0	0.9	4.5
Interior Watertight Door (16' x 14') (Al)	10	2.17	21.7	0.6	16.8
Subtotal			124.2		40.4
Removable 3rd Deck* (48,000 sq. ft.) (Al)	1	171	171	-	-
Removable 4th Deck** (43,105 sq. ft.) (Al)	1	188	188	-	-
			483.2		

* Removable 3rd Deck is used for the Airborne Division only and included as part of the payload weight.

** Portions of 4th Deck are removable and included as part of the payload weight.

TABLE 6-iv

a. Establishing feasibility of payload stowage and handling

b. Identifying area requirements for access and payload manipulation

c. Identifying essential ship arrangement features

6.1.4.1 Payload Stowage and Handling

Payload requirements were evaluated in terms of area and weight to establish preliminary ship loads and distribution of cargo. Analysis established the feasibility of payload stowage/handling and finalized ship loading.

Two ships are required to transport a complete Airborne Division and five ships are required for an Armored Division. The number of ships was determined by the cargo area and weight in Tables 6-i and 6-ii and utilization of a 3,900 nm range and corresponding payload weights/ ship displacements of Figure 3-5.

Figures 6-5 and 6-6 show the cargo arrangement for 1/2 of an Airborne Division. Figures 6-7 and 6-8 show the cargo arrangement for 1/5 of an Armored Division. Tables 6-v and 6-vi specify the payload distribution for both cargo arrangements. The initial allowance of 25% for access area increased to 75% after completion of the cargo arrangement analyses. This 75% access area increased the gross area to 467,952 sq. ft. per Airborne Division and 820,864 sq. ft. per Armored Division. This increase in access area permits rapid stowage and unloading of cargo. Figures 6-5 and 6-6 indicate that there is considerable space available for additional Airborne Division cargo if the need arises. Payload handling characteristics impacting on access area requirements are shown in Table 6-vii.

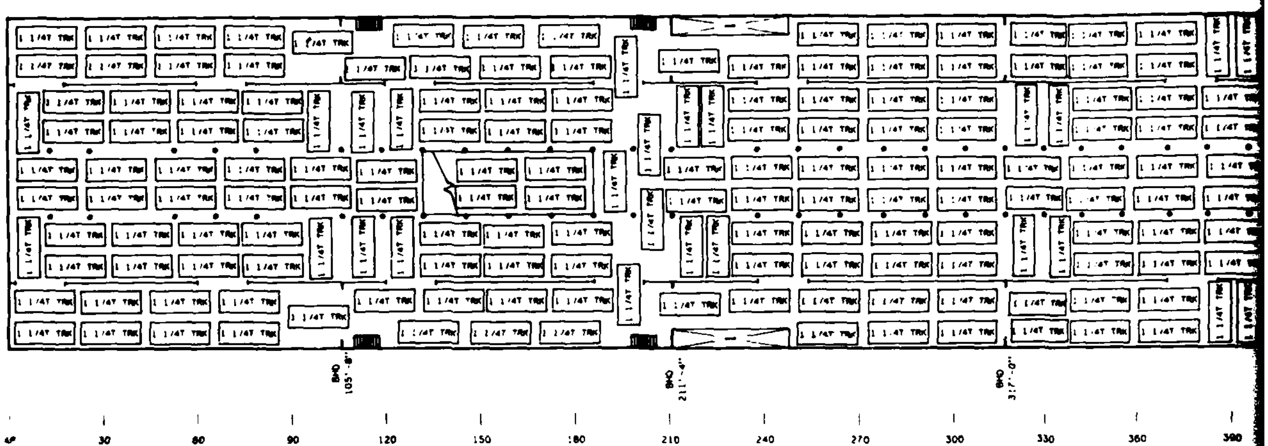
Stowage of the Airborne Division is limited by the available cargo deck area of 234,683 sq. ft. Stowage of the Armored Division is limited by the payload carrying capacity of 6,200 LT for a 3,900 nm range and 15,000 LT ship displacement as shown in Figure 3-5.

The total ship capacity on the main and fifth decks is 548 40-foot containers or 1,270 20-foot containers. One ship can carry 413 40-foot containers or 563 20-foot fully loaded containers. Stowage of these containers is limited by the payload weight carrying capacity of 6,200 LT for 3,900 nm range. Table 6-viii shows the arrangement of the containers on the 1st and 5th decks. Containers are handled by overhead pier cranes for stowage on the 1st (Main) deck and by forklifts, straddle carriers and/or tractor-trailers for stowage on the 5th (Tank) deck.

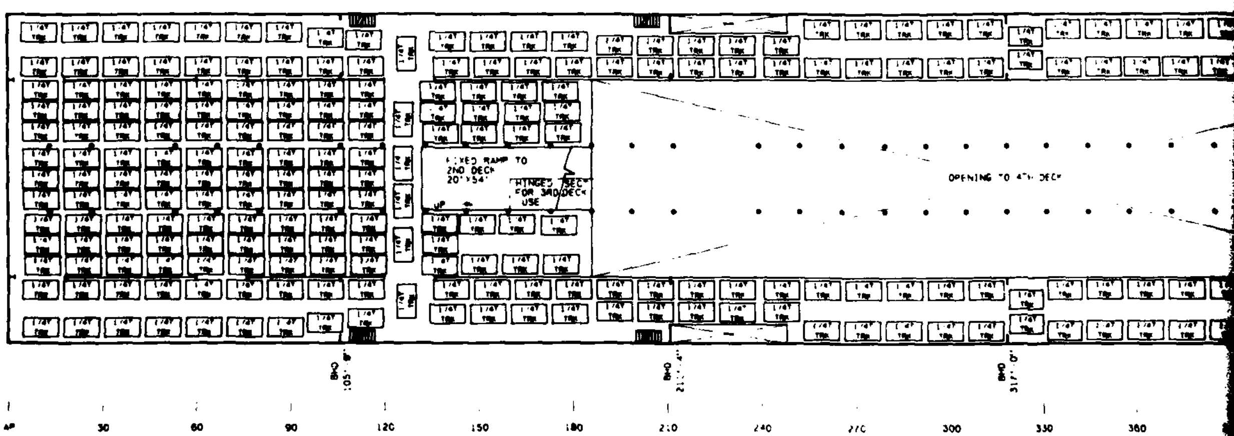
6.1.4.2 Area Requirements for Access and Handling

The definition of external and internal handling systems and the iterative cargo arrangement studies for payload handling feasibility were

ARRANGEMENT OF 1/2 AIRBORNE DIVISION ON

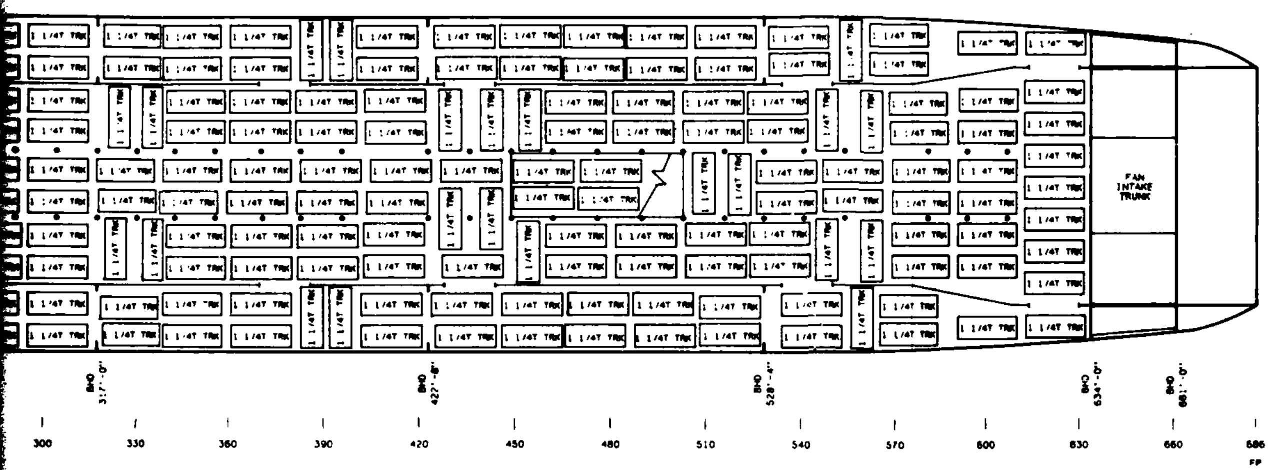


2ND DECK
9'-0" CLEARANCE
65' ABL

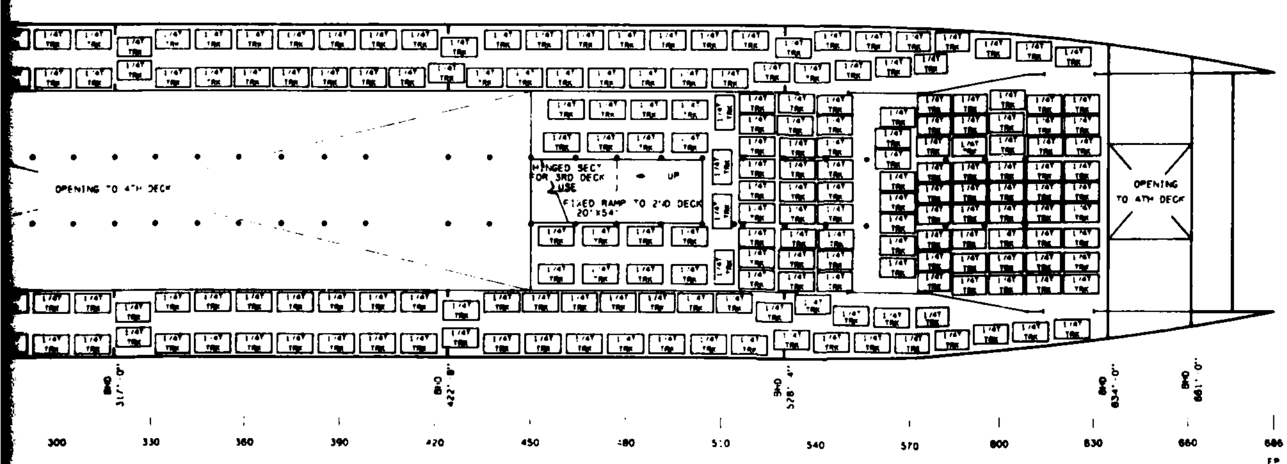


3RD DECK (CAR DECK)
6'-5" CLEARANCE
58' ABL

AIRBORNE DIVISION ON SECOND & THIRD DECKS



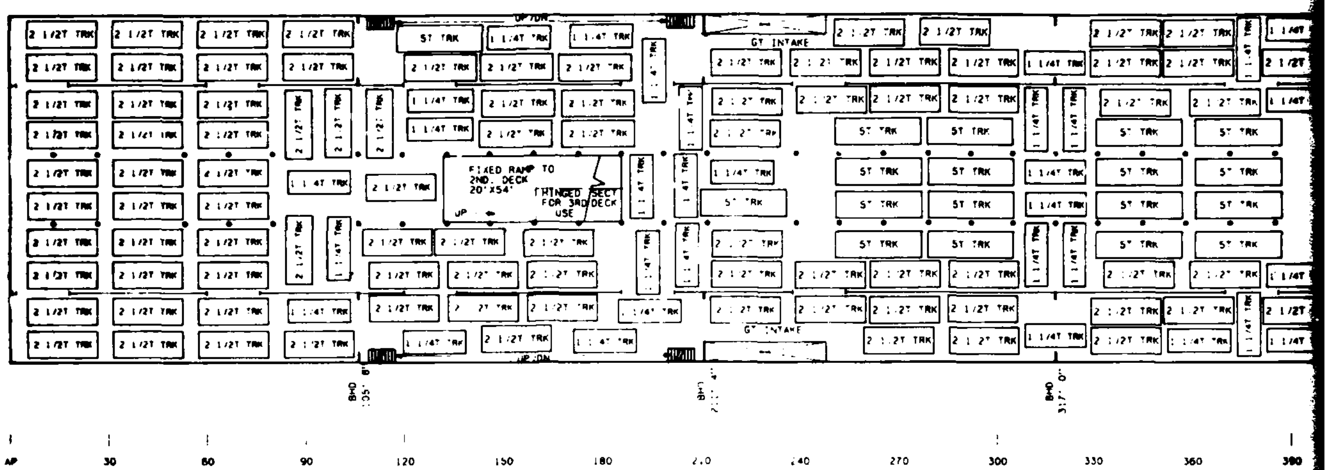
2ND DECK
9'-0" CLEARANCE
65' ABL



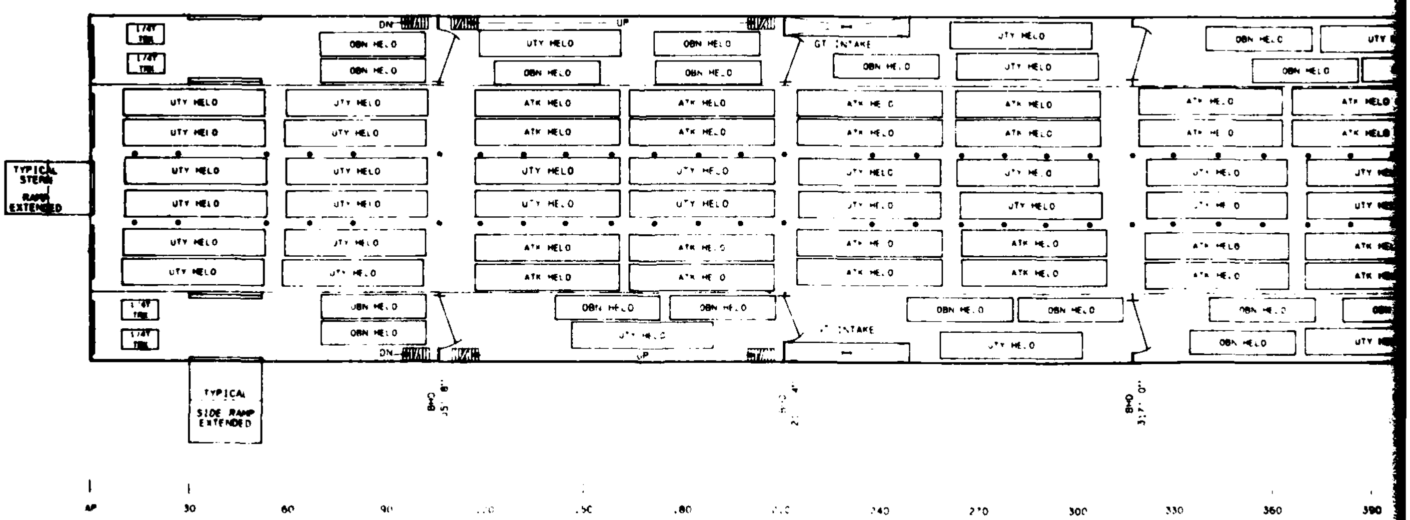
D DECK (CAR DECK)
8'-5" CLEARANCE
58' ABL

FIGURE 6–5

ARRANGEMENT OF 1/2 AIRBORNE DIVISION ON

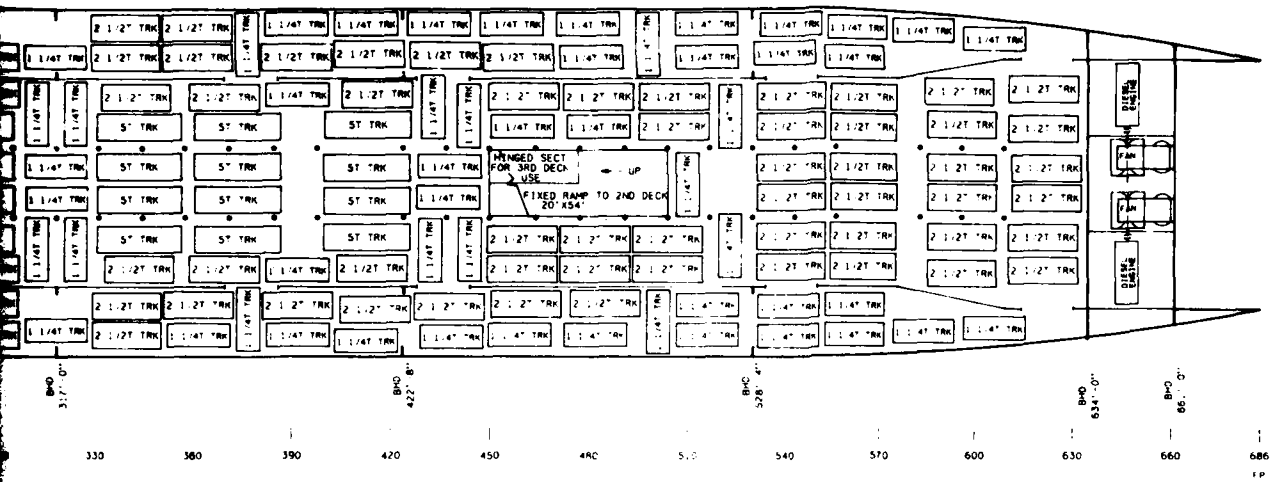


4TH DECK
8'-7" CLEARANCE
49' ABL

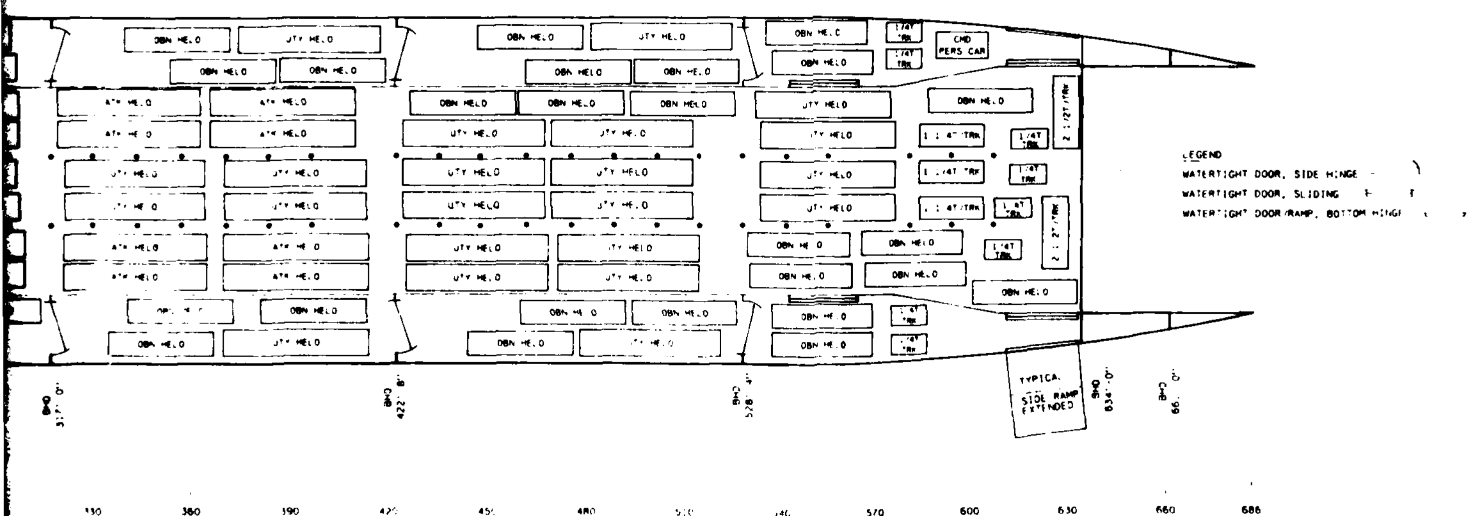


5TH DECK (TANK DECK)
15'-0" CLEARANCE
33' ABL

BORNE DIVISION ON FOURTH & FIFTH DECKS



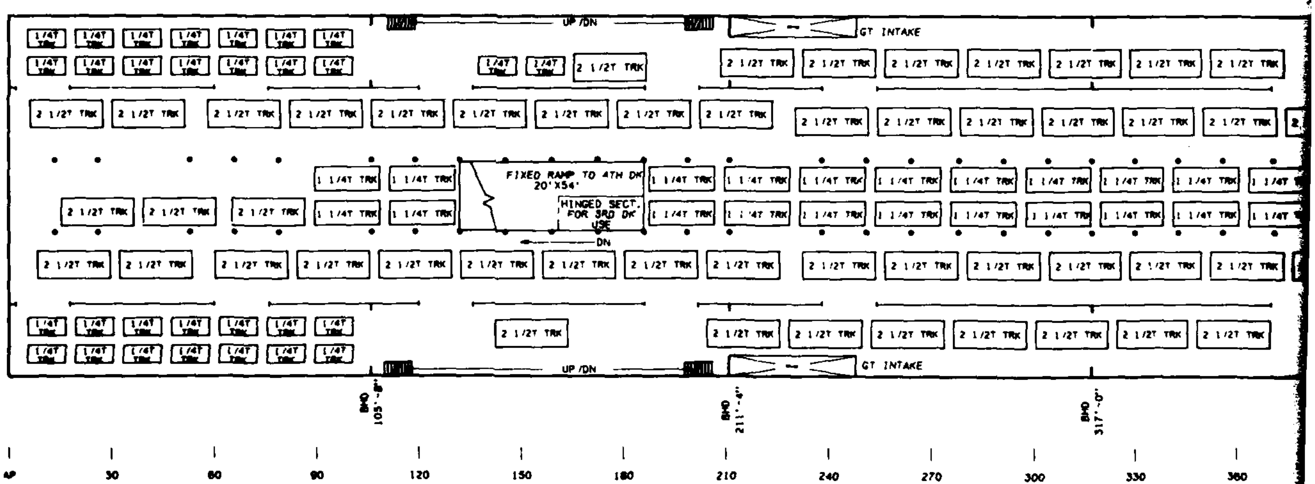
TH DECK
" CLEARANCE
49' ABL



(TANK DECK)
" CLEARANCE
3' ABL

FIGURE 6–6

ARRANGEMENT OF 1/5 ARMORED DIVISIO



2ND DECK
9'-0" CLEARANCE
65' ABL

ARMORED DIVISION ON SECOND DECK

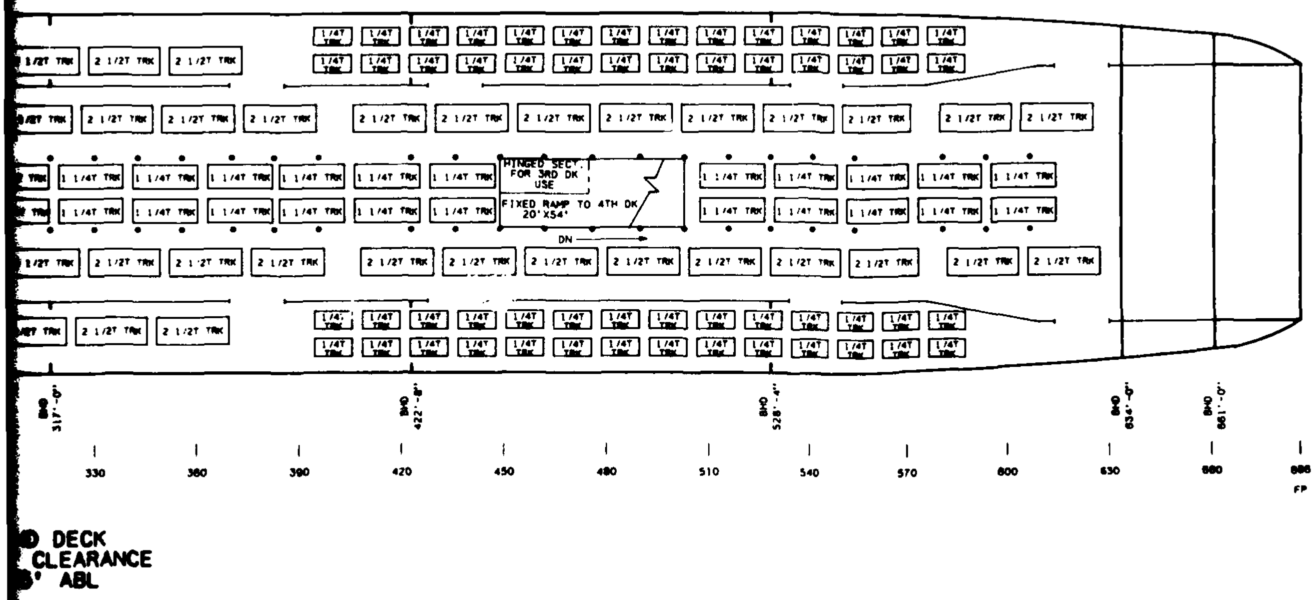
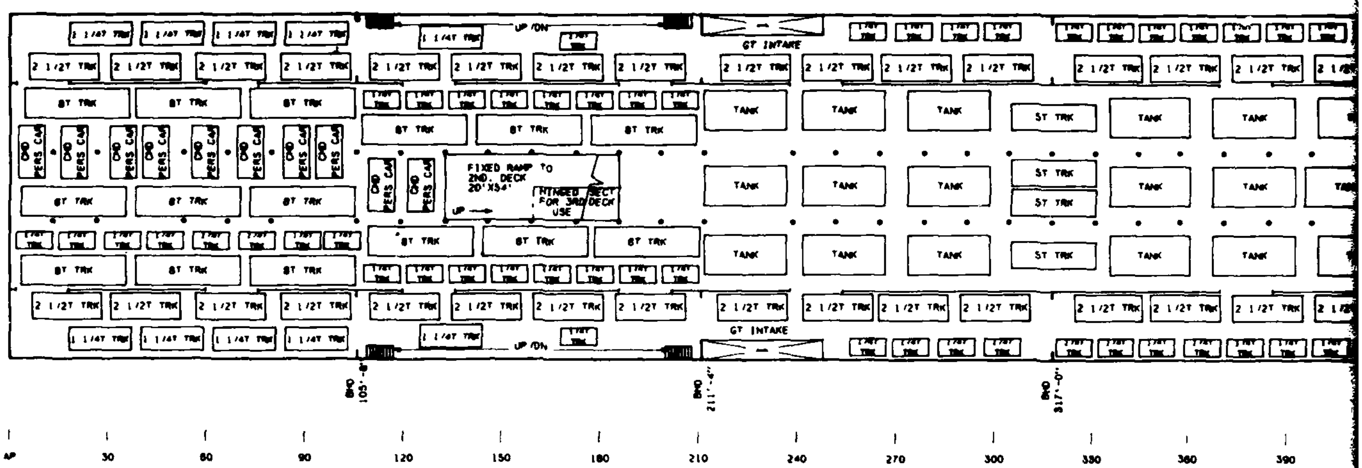
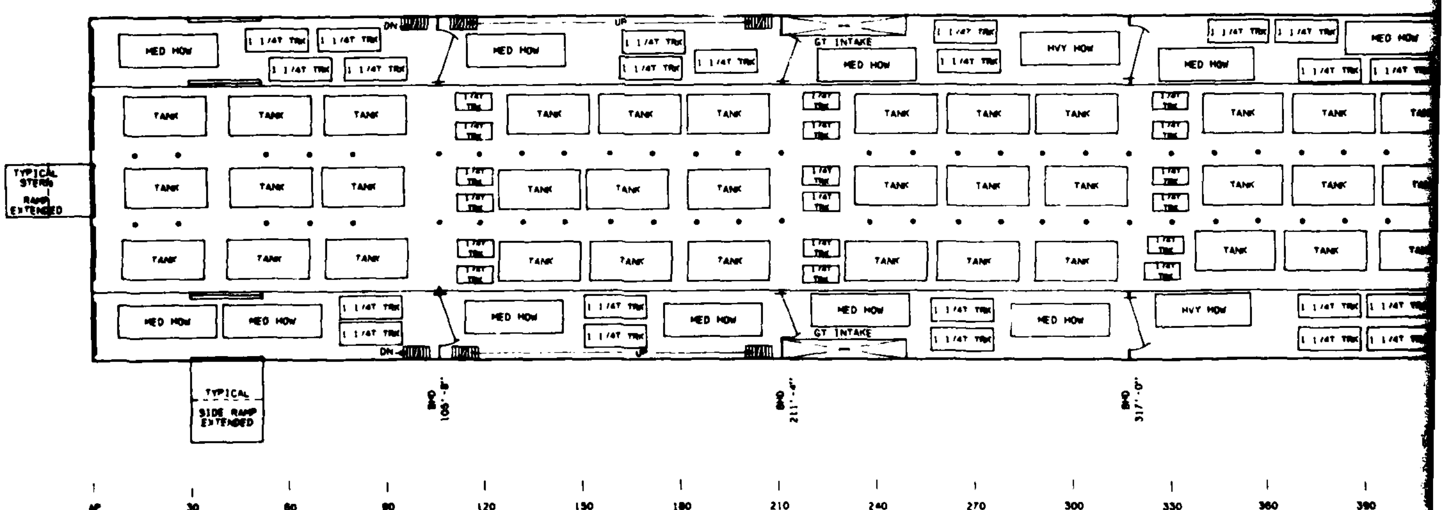


FIGURE 6-7

ARRANGEMENT OF 1/5 ARMORED DIVISION ON



4TH DECK
15'-0" CLEARANCE
49' ABL



5TH DECK (TANK DECK)
15'-0" CLEARANCE
33' ABL

RMORED DIVISION ON FOURTH AND FIFTH DECKS

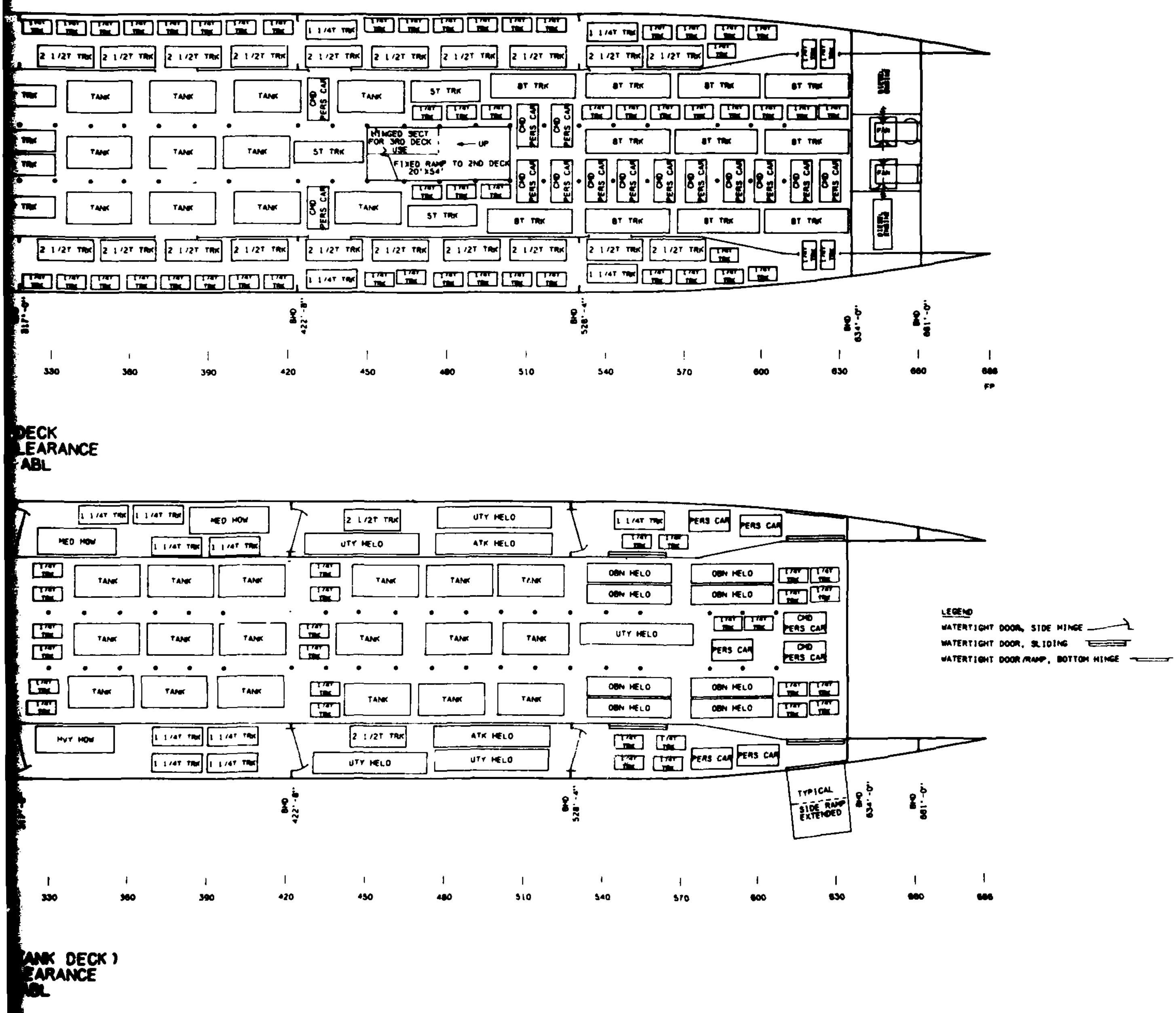


FIGURE 6–8

2

PAYLOAD DISTRIBUTION FOR 1/2 AIRBORNE DIVISION ARRANGEMENT

KEY	EQUIPMENT	5th DECK QTY	5th DECK WT LT	4th DECK QTY	4th DECK WT LT	3rd DECK QTY	3rd DECK WT LT	2nd DECK QTY	2nd DECK WT LT	TOTAL QTY	TOTAL WT LT
5T TRK	Truck, 5 ton, cargo			22	213.4					22	213.4
2 1/2T TRK	Truck, 2 1/2 ton, cargo	2	12.2	133	811.3					135	823.5
1 1/4T TRK	Truck, 1 1/4 ton, cargo	3	9.9	68	224.4			276	910.8	347	1145.1
1/4T TRK	Truck, 1/4 ton, utility	12	13.2			388	426.8			400	440.0
ATK HELO	Helicopter, attack	24	55.2							24	55.2
UTY HELO	Helicopter, utility	47	103.4							47	103.4
OBN HELO	Helicopter, observation	37	29.6							37	29.6
CMD PERS CAR	Carrier, command personnel	1	10.0							1	10.0
	SUBTOTAL (WT)		233.5		1,249.1		426.8		910.8		2,820.2
	TIEDOWNS (5% WT)		11.7		62.5		21.3		45.5		141.0
	TOTAL	126	245.2	223	1,311.6	388	448.1	276	956.3		
	GRAND TOTAL (GROSS)									1,013	2,961.2

NOTE: See Figures 6-5 and 6-6 for 1/2 Airborne Division arrangement.

TABLE 6-v

PAYLOAD DISTRIBUTION FOR 1/5 ARMORED DIVISION ARRANGEMENT

KEY	EQUIPMENT	5th DECK		4th DECK		2nd DECK		TOTAL	TOTAL
		QTY	WT LT	QTY	WT LT	QTY	WT LT	QTY	WT LT
Tank	Tank, combat, M60	45	1,948.5	20	866.0			65	2,814.5
8T TRK	Truck, 8 ton, cargo			26	291.2			26	291.2
5T TRK	Truck, 5 ton, cargo			7	67.9			7	67.9
2 1/2T TRK	Truck, 2 1/2 ton, cargo	2	12.2	44	268.4	84	512.4	130	793.0
1 1/4T TRK	Truck, 1 1/4 ton, cargo	24	79.2	14	46.2	30	99.0	68	224.4
1/4 T TRK	Truck, 1/4 ton, utility	40	44.0	92	101.2	22	24.2	154	169.4
ATK HELO	Helicopter, attack	2	4.6					2	4.6
UTY HELO	Helicopter, utility	5	11.0					5	11.0
OBN HELO	Helicopter, observation	8	6.4					8	6.4
PERS CAR	Carrier, personnel	5	44.5			110	979.0	115	1,023.5
CMD PERS CAR	Carrier, command personnel	2	20.0	24	240.0			26	260.0
MED HOW	Howitzer, medium	11	239.8					11	239.8
HVY HOW	Howitzer, heavy	2	53.6					2	53.6
	SUBTOTAL (WT)		2,463.8		1,880.9		1,614.6		5,959.3
	TIEDOWNS (5% WT)		123.2		94.1		80.7		298.0
	TOTAL	146	2,587.0	227	1,975.0	246	1,695.3		
	GRAND TOTAL (GROSS)							619	6,257.3

NOTE: See Figures 6-7 and 6-8 for 1/5 Armored Division arrangement.

TABLE 6-vi

PAYLOAD EQUIPMENT HANDLING CHARACTERISTICS

EQUIPMENT (TOE Line Item Number)	GROUND CLEARANCE (In)	OUTSIDE TURNING RADIUS (Ft)	TECHNICAL MANUAL NUMBER	CURRENT DATE
TANK, combat (V13101), M60A1	18.2	29.5	TM9-2350-215-10	02/03/65
TRUCK, 8 ton, cargo (X41653), M520WWN	23.3	27.3	TM-9-2320-233-10	06/07/76
TRUCK, 5 ton, cargo (X40968), M813WWN	10.6	41.8	TM9-2320-260-10	11/30/77
TRUCK, 2 1/2 ton, cargo (X40146), M35A2WWN	10.9	36.0	TM9-2320-209-10-1	10/29/76
TRUCK, 1 1/4 ton, cargo (X39940), M561WWN	15.0	29.0	TM9-2320-242-10	03/04/77
TRUCK, 1/4 ton, utility (X60833), M151A2	10.3	17.9	TM9-2320-218-10	08/10/78
HELICOPTER, attack (K29660), AH-1G		44.8*	TM55-1520-221-10	12/12/75
HELICOPTER, utility (K31795), UH-H		41.4*	TM55-1520-210-10	08/25/71
HELICOPTER, observation (K31042), OH-58A		32.2*	TM55-1520-228-10	04/07/78
CARRIER, personnel (D12087), M113A1	16.0	12.6	TM9-2300-257-10	08/25/78
CARRIER, command personnel (D11538), M577A1	16.0	12.6	TM9-2300-257-10	08/25/78
HOWITZER, medium (K57667), M109A1 SP	18.0	**	TM9-2350-217-10	12/13/69
HOWITZER, heavy (K56981), M110A1 SP	17.0	**	TM9-2300-216-10	07/28/77

* Main rotors are not installed.
** Dependent upon prime mover.
SP Self Propelled

TABLE 6-vii

principal factors in establishing cargo access requirements. Cargo egress points and internal flow patterns determined payload manipulation area requirements. Significant ship design factors influencing these area requirements were ship's structure (e.g., structural bulkheads and stanchions) and the watertight sidehull bulkheads on the 5th deck.

Major access space requirements exist in the area of the sidehull watertight doors as shown in the Airborne and Armored Division arrangement drawings, Figures 6-5, 6-6, 6-7, and 6-8, respectively. Payload handling and stowage requirements coupled with the sidehull watertight bulkheads required utilization of large, watertight doors. Ship bulkheads and stanchions were adjusted to insure a balance between space utilization and structural efficiency.

ARRANGEMENT OF CONTAINERS

Deck	40-Foot Containers	20-Foot Containers
1st (Main)	281	319
5th (Tank)	132	244
TOTAL	413	563

TABLE 6-viii

6.1.4.3 Ship Arrangement Considerations

Results of the analysis performed for this report support the need for the following essential considerations for RO/RO operations:

a. Segregation of RO/RO and non-RO/RO cargo is essential to maximize cargo handling efficiency and minimize required pier facilities.

b. Ramp and door positions must be designed to allow traffic flow to alternate routes if any single path is blocked.

c. Minimum angle (usually 5 degrees or less) external access ramps are required for RO/RO operations, especially for helicopters with wheeled cradles. The ability to use the ship's lift fans and/or ballast systems to minimize ramp angles by compensating for various pier heights and tide effects is desirable.

d. Clearance between vehicles and between vehicles and ship's structure must be at least 2 ft. to allow for access and securing.

e. A minimum outside turning radius of 42 ft. is required for 5 ton cargo trucks.

f. Personnel access must be available to all cargo stowage areas for fire protection, surveillance, and maintenance.

6.1.5 Preliminary Time Line Analysis

The purpose of this analysis was to determine the in-port time required for loading and offloading of military cargo.

6.1.5.1 Approach

The analysis was based on the following assumptions:

a. Ship ballasting and deballasting operations are completed by the time the load or offload of cargo commences.

b. Vehicles are aligned in proper sequence on pier and no delay will be incurred in loading vehicles onto ramp.

c. All drivers are skilled.

d. Tiedown attachment will not delay loading or offloading.

e. Sufficient personnel are available for securing or unsecuring, starting, and driving of vehicles to fulfill flow requirements.

f. Shoreside dispersal and staging areas are non-constraining.

g. Ship is secured and all stern or sideport ramps in place at time zero.

h. Simultaneous loading/offloading of only two rows of RO/RO cargo when using stern or side port ramps in order to keep the time estimate very conservative.

i. Simultaneous loading/offloading of cargo areas on all decks except the 5th to provide a sufficient maneuvering area and time such that flow is not delayed as long as the initial vehicle in sequence is assumed to transit the maximum distance.

j. Cargo stowage is optimal for a predetermined loading/offloading method.

k. Average cargo spacing is approximately one vehicle length or an average of 2[illegible] ft. for vehicles and 40 ft. for helicopters.

The total loading time consists of the greater sum of the times required to maneuver each vehicle in each row into its parking position plus the time required for the first vehicle to cross the ship ramp position and be located in its assigned parking area, i.e.,

$$\text{Load Time} = TL = T_{t_1} + (T_{m_1} + \ldots + T_{m_n})$$

Where: T_{t_1} = Traverse time of first vehicle in the sequence
T_m = Maneuvering time from arrival in parking location until finally parked.

The total offload time consists of the greater sum of the times required for each vehicle in each row to maneuver out of its parked position to join the free stream plus the time required for the last vehicle to depart the shore ramp, i.e.,

$$\text{Offload Time} = TO = (T_{m_1} + \ldots + T_{m_n}) + T_{t_n}$$

Where: T_m = Maneuvering time from parked position to free stream.
T_{t_n} = Traverse time of last vehicle in the row from parked position to shore.

6.1.5.2 Analysis

Estimated transit time for the first vehicle in each sequence was based on the distance required to park or unpark the vehicle. This estimate included the outside turning radius of the vehicle and free stream direction. Traverse times were established upon an average vehicle speed of 1 1/2 MPH and a helicopter towing speed of 1/2 MPH, assuming the use of all stern or side port access ramps. Sample calculations of the time line analyses are provided in Appendix B.

6.1.5.3 Results

Results of the preliminary time line analyses are shown below for the Airborne and the Armored Division arrangements.

CARGO TYPE	FRACTION OF DIVISION PER SHIP	PAYLOAD WEIGHT	LOAD TIME (HRS.)	OFF LOAD TIME (HRS.)
Airborne Division	1/2	2966 LT	9.2	11.9
Armored Division	1/5	6263 LT	5.3	5.5

Stern ramps were used for cargo loading, and side ramps were used for cargo offloading. If only one side ramp were available, cargo offloading would be performed through the side ramp near the bow. Use of only one side ramp results in the following offload times: 18.3 hours for half an Airborne Division; and 7.4 hours for 1/5 of an Armored Division. If all stern and side ramps were used and 10 lanes of traffic established, the load and offload times for half an Airborne Division would be less than 3.5 hours.

6.1.6 Summary of Payload Interface Trade Study

Results of the payload interface analysis provide the initial selection of cargo stowage arrangements, access and handling systems and preliminary time lines. The selection of the RO/RO loading and offloading

concept was the primary factor in determining most aspects of the cargo access and handling system. The MPS with a removable 3rd deck is the optimum design for transport of the Airborne Division in two shiploads. Increasing the payload capability to 6,263 LT is optimal for transport of the Armored Division in five shiploads. The MPS also has the capability to transport 413 40-foot containers or 563 20-foot fully loaded containers.

6.2 LOGISTICS CONSIDERATIONS

This task consisted of development of typical ship operating profiles and discussion of peculiar logistics-related requirements and required support activities.

6.2.1 Operating Profiles

Typical operating profiles were developed for the scenario in which the MPS is called upon to deliver various types and quantities of Airborne Division, Armored Division, and containerized cargo during a 30-day mobilization mission. The nominal range of the MPS was selected as 3,900 nm. Payload weights and MPS speeds were varied to optimize the number of ship deliveries during the mission duration. The time to complete one round trip included the following events: fuel and tie up at dock, load cargo, ocean transit, refuel at sea for some cases, tie up at dock, offload cargo, refuel at dock, and return trip with no cargo. The average speed on the return trip with no payload is 68 knots. Rationale for these operating profiles is provided in Appendix C.

Table 6-ix provides several operating profiles for a 30-day mobilization mission. Cases 1 and 2 represent the maximum quantity of payload that can be delivered in 5 trips over a 3,900 nm range in 30 days. Average speeds of 47 kt or greater in cases 1 and 2 are derived from Figure 2-2. These speeds allow rapid deliveries of the payload in 4 days per trip. By refueling at-sea, 1,000 LT of additional payload can be delivered at a slightly higher speed.

Cases 3 and 4 represent the maximum quantity of payload that can be delivered in 4 trips over a 3,900 nm range in 30 days. Average speeds of 33 kt or greater versus 47 kt for cases 1 and 2 are traded off against larger quantities of payload delivered, i.e., 26,400 LT for case 4 versus 18,500 LT for case 2. Additional payload of 2,400 LT can be carried in 30 days by refueling at-sea.

Several examples of the different types and quantities of cargo that can be delivered by the MPS are shown in Tables 6-x through 6-xii. The MPS can deliver 32 Armored Divisions, consisting of 10,240 tanks, 86,400 vehicles, 2,240 helicopters, and 53,856 LT of combat support equipment, ammunition and fuel with 40 ships during a 30-day mission as shown by Table 6-x. Using 20 ships for cargo delivery in 30 days, the MPS can deliver 40 Airborne Divisions, consisting of 72,480 vehicles, 8,560 helicopters and 290,720 LT of combat support equipment, ammunition, and

fuel as shown in Table 6-xi. The versatility of the MPS is shown in Table 6-xii which demonstrates the MPS capability to deliver 40-foot or 20-foot containers.

OPERATING PROFILES FOR 30-DAY MISSION

EVENT	CASE 1 3,500 LT Payload No At-Sea Refuel	CASE 2 3,700 LT Payload At-Sea Refuel	CASE 3 6,000 LT Payload No At-Sea Refuel	CASE 4 6,600 LT Payload At-Sea Refuel
Fuel & Dock Tie Up (Hrs)	5	5	5	5
Load Cargo (Hrs)	3.1	3.3	5.2	5.5
Ocean Transit (Hrs)	82.1	78.8	116.4	113.0
Refuel At Sea (Hrs)	-	3	-	3
Dock Tie Up (Hrs)	2	2	2	2
Offload Cargo (Hrs)	3.1	3.3	5.4	5.7
Refuel At Dock (Hrs)	3	3	3	3
Return (No Cargo) (Hrs)	57.4	57.4	57.4	57.4
1st Round Trip (Hrs)	155.7	155.8	194.4	194.6
2nd Round Trip (Hrs)	155.7	155.8	194.4	194.6
3rd Round Trip (Hrs)	155.7	155.8	194.4	194.6
4th Round Trip (Hrs)	155.7	155.8	134.0*	134.2*
5th Round Trip (Hrs)	95.3*	95.4*	-	-
Total Delivery (Hrs)	718.1	718.6	717.2	718.0
Total Delivery (Days)	29.9	29.9	29.9	29.9
Contingency (Days)	0.1	0.1	0.1	0.1
1st Delivery (Days)	4.0	4.0	5.6	5.6
1st Round Trip (Days)	6.5	6.5	8.1	8.1
Total Delivered Payload LT	17,500	18,500	24,000	26,400
Average Speed Out (kt)	47.5	49.5	33.5	34.5

* one-way trip only, no return trip

TABLE 6-ix

6.2.2 Logistics and Support Concepts

Peculiar logistics-related requirements and required support activities for the MPS are discussed in the Maintenance and Support Concept and Reliability and Availability Concept section.

6.2.2.1 Maintenance and Support Concept

The ship system design incorporates provisions which maximize equipment utilization and minimize requirements for at-sea maintenance. The

maintenance concept for meeting the objectives and availability goal of the MPS is to perform operational and corrective maintenance on critical equipments aboard, and defer or schedule all non-essential equipments and components maintenance for in-port availabilities.

DELIVERY OF ARMORED DIVISION EQUIPMENT DURING A 30 DAY PERIOD

	DELIV-ERIES	TOTAL DELIVERED PAYLOAD LT	DIVI-SIONS	TANKS	VEHI-CLES	HELI-COPTERS	COMBAT SUPPORT LT
1st Delivery	1	6,600	0.2	64	540	14	337
1 Ship Delivers	4	26,400	0.8	256	2,160	56	1,346
10 Ships Deliver	40	264,000	8	2,560	21,600	560	13,464
20 Ships Deliver	80	528,000	16	5,120	43,200	1,120	26,928
30 Ships Deliver	120	792,000	24	7,680	64,800	1,680	40,392
40 Ships Deliver	160	1,056,000	32	10,240	86,400	2,240	53,856

TABLE 6-x

DELIVERY OF AIRBORNE DIVISION EQUIPMENT DURING A 30 DAY PERIOD

	DELIV-ERIES	TOTAL DELIVERED PAYLOAD LT	DIVI-SIONS	VEHI-CLES	HELI-COPTERS	COMBAT SUPPORT LT
1st Delivery	1	6,600	0.5	906	107	3,634
1 Ship Delivers	4	26,400	2	3,624	428	14,536
10 Ships Deliver	40	264,000	20	36,240	4,280	145,360
20 Ships Deliver	80	528,000	40	72,480	8,560	290,720
30 Ships Deliver	120	792,000	60	108,720	12,840	436,080
40 Ships Deliver	160	1,056,000	80	144,960	17,120	581,440

TABLE 6-xi

DELIVERY OF CONTAINERIZED CARGO DURING A 30 DAY PERIOD

	40-FOOT CONTAINERS		OR	20-FOOT CONTAINERS	
	QUANTITY	WEIGHT LT		QUANTITY	WEIGHT LT
1st Delivery	440	6,600		600	6,600
1 Ship Delivers	1,760	26,400		2,400	26,400
10 Ships Deliver	17,600	264,000		24,000	264,000
20 Ships Deliver	35,200	528,000		48,000	528,000
30 Ships Deliver	52,800	792,000		72,000	792,000
40 Ships Deliver	70,400	1,056,000		96,000	1,056,000

TABLE 6-xii

For design purposes, particular emphasis will be given to: (1) maximum use of existing equipment items to permit use of standard maintenance procedures and supply support; (2) use of performance and condition monitoring for detecting incipient failures for critical equipment; and (3) provisions for equipment accessibility to support a component and module replacement strategy. The replacement strategy includes scheduled replacement, replacement on condition, and replacement at failure depending on the subsystem and equipment criticalities.

Ship systems will be designed for maximum redundancy and to permit incremental overhaul of subsystems, subsystem accessories and related auxiliaries. Major maintenance actions will be accomplished by ashore contractor maintenance activities during periodic upkeep and maintenance availabilities in accordance with ship utilization schedules. These contractor maintenance activities will perform all conditional, preventive, and corrective maintenance beyond the capability of ship personnel.

Built-in test equipment will provide continuous and periodic monitoring of critical functions and equipments, such as ship electronics and machinery systems. Special purpose tools and test equipment as well as standard tools will be provided as ship's tool items.

No additional personnel will be assigned for the sole purpose of performing maintenance. Operational maintenance performed by the crew will be in accordance with ship systems operational maintenance requirements. Condition monitoring equipment will be installed in mission-essential

systems. Corrective maintenance actions will be performed to maintain equipment in an operational state and be accomplished through replacement of defective or degraded subassemblies within equipments or through replacement of the equipments themselves. Arrangement design will ensure adequate accessibility to equipments for maintenance without necessitating secondary structure rip-out or equipment removal.

Regular overhauls are to be minimized by intensive use of upkeep periods as maintenance availability periods. The MPS will employ the concept of progressive equipment overhaul, replacement, and alteration during relatively frequent maintenance availability periods of short duration. Dry-docking will be accomplished, primarily for major emergency repairs and ship alterations. The ship system will be designed to be capable of incremental overhaul of its subsystems and subsystem accessories and related auxiliaries. Operational usage and scheduled replacement will be consistent with the major item replacement schedule. Equipment removal routes will be established for transverse and vertical movements of large equipments, such as propulsion and lift engines in order to preclude structural rip-outs and removal of other equipments.

Employment of a replace-before-failure maintenance strategy in conjunction with a minimum manning philosophy requires that a significant number of equipments be removed for rotatable pool replacement and offship repair/refurbishment. The manning concept is discussed in Section 5.1 of this report.

6.2.2.2 Reliability and Availability Concept

MPS reliability and availability will be high because the maintenance and support concept minimizes the requirements for at-sea maintenance. Repairable items are sent ashore to intermediate or depot level repair facilities using the rotatable pool concept. Replacement parts will be carried on-board to assure that critical equipments are maintained on-line, or that equipments are redundant to assure continuous operation by placing back-up equipment on-line. Automatic monitoring systems will be used to indicate equipment malfunction in order to minimize the use of watch station personnel.

Systems requiring high reliability and availability include:

a. Propulsion Turbines and Transmission - include redundant lubrication system.

b. Electric Plant - includes highly reliable diesels, proven components, multiple switchboards.

c. Command and Surveillance - include redundant modules, plug-in replacements.

d. Lift System - either bank of fans can provide adequate performance over most on-cushion operations. Transmission is simple, in-line shaft type.

e. <u>Seals</u> - Seal fingers are capable of repair without drydocking.

7. CONCLUSIONS

o The analysis which supports this report used well-established ship design techniques and is fully supported by years of analysis, model tests, full-scale craft tests, system tests and computer modelling. It was purposely conservative to ensure a substantive and reliable basis for the predicted performance.

o The analysis also establishes conclusively the fuel-efficient nature of the SES hull, and the impressive performance that can be derived by applying common design and ship-building techniques.

o The MPS hull and structure is highly amenable to automated fabrication techniques and the ship could be built economically with current production-run hardware and systems, and within the same planning/building cycle normally associated with conventional ship programs.

o The design approach which used 100% buoyant sidehulls with a high wet deck proved to be a significant step forward in simplifying many aspects of SES design. The drag penalty was low, hull loading (and the attendant design/construction complications) diminished substantially and economical off-cushion operations emerged as a practical and significant capability.

o The use of lightweight fuel-efficient diesels for lift and propulsion was found to offer a number of important advantages.

o The capability to build the MPS in the U.S. Shipbuilding Industry exists today.

8. APPENDICES

Section 8 contains three appendices. Appendix A provides a comparison of the MPS with other cargo ships. Appendix B contains preliminary and sample calculations of cargo loading/offloading times, and helicopter towing limitations. Appendix C, discusses the operating profile rationale for the MPS.

APPENDIX A
COMPARISON OF MPS WITH OTHER CARGO SHIPS

The following discussion summarizes the features of an MPS along with other cargo ships.

A.1 PRINCIPAL CHARACTERISTICS

Three ships were selected for comparison to the MPS. One, the SL-7, is already in operation and specializes in container cargoes. To this end, it was compared to the MPS only in this mode. Two other ships, the PD-214 (MA-134) and T-AKX (JUMBO PD-214), were also used for comparison because, like the MPS, they can carry RO/RO, or container cargo. Principal characteristics are listed in Table A-i.

A.2 CARGO

Figure A-1 represents the plan form of an MPS and that of a conventional cargo ship. Conventional ships, of necessity must taper the cargo load fore and aft of the center body because the hull tapers down for hydrodynamic reasons. Thus, the ability of a ship to carry cargo is compromised. Furthermore, cargo compartments are disrupted by the machinery spaces in the lower decks, and by the pilot house and living spaces in the upper decks. The MPS, on the other hand, is so arranged that the cargo decks run the full length and width of the ship. Machinery spaces are located beneath the lowest cargo deck (in fact, additional cargo space can be made available in the machinery flat). The pilot house and the living spaces are completely above the main deck. Hatched areas in Figure A-1 indicate the space available for cargo on the MPS, but not available for cargo on conventional ships.

Two basic payload types were selected in order to compare the cargo carrying efficiency of the ships under analysis, container and RO/RO. Calculations are summarized in Tables A-ii and A-iii.

The SL-7 which is designed to carry containers has a load efficiency (payload-to-FLD) of 0.29, while the MPS load efficiency is 0.56 as shown in Table A-ii. This interesting parameter indicates that 56% of the MPS FLD is assigned to cargo while 35% is assigned on the PD-214 and the T-AKX, and 29% on the SL-7. Transport efficiency ((cargo weight x speed) /nm travelled) favors the SL-7 for two reasons: First, its large cargo capacity relative to any of the other ships, and second, because it can maintain 33 knots.

Transport efficiency increases with payload size for RO/RO cargo as shown in Table A-iii. PD-214 carrying the same loads as assigned to the MPS but limited to 1/5 airborne, or 1/9 armored, because the size of the available cargo area is limited, has been included for comparison.

PRINCIPAL CHARACTERISTICS OF CARGO SHIPS

CHARACTERISTICS	MPS	PD-214	T-AKX	SL-7
Length Overall, ft	686	609	719	946.1
Length Between Perpendiculars, ft	686	560	670	880.5
Beam, ft	105	97	97	105.5
Depth, ft	75	61.5	61.5	64.0 (Forward) 68.5 (Aft)
Draft (Design), ft	30.4	30	30	30
Displacement (Maximum), LT	15,000	28,870	37,830	51,815
Lightship Weight, LT	5,388	12,320	14,520	22,915
Total Deadweight, LT	9,612	16,550	23,310	27,144
Total Payload, LT	6,200	13,750	19,860	15,000***
Shaft Horsepower	120,000	22,500	22,500	120,000
Speed Maximum, knots (30-ft draft)	68*	20	20	33
Range, nm, at maximum speed	3,900**	11,100	11,900	6,000
Gross Tonnage	28,800	15,900	19,640	41,127

* Maximum speed, no payload. Speed varies with payload. Minimum on-cushion speed is 34 knots at maximum payload.

** Off-cushion, operating with two SACM diesels, range is 15,000 nm at 15 knots and 9,000 LT payload.

*** 1,000 - 40 ft containers. Payload is 22,000 LT with 2,000 - 20 ft containers.

TABLE A-i

CARGO SPACE COMPARISON

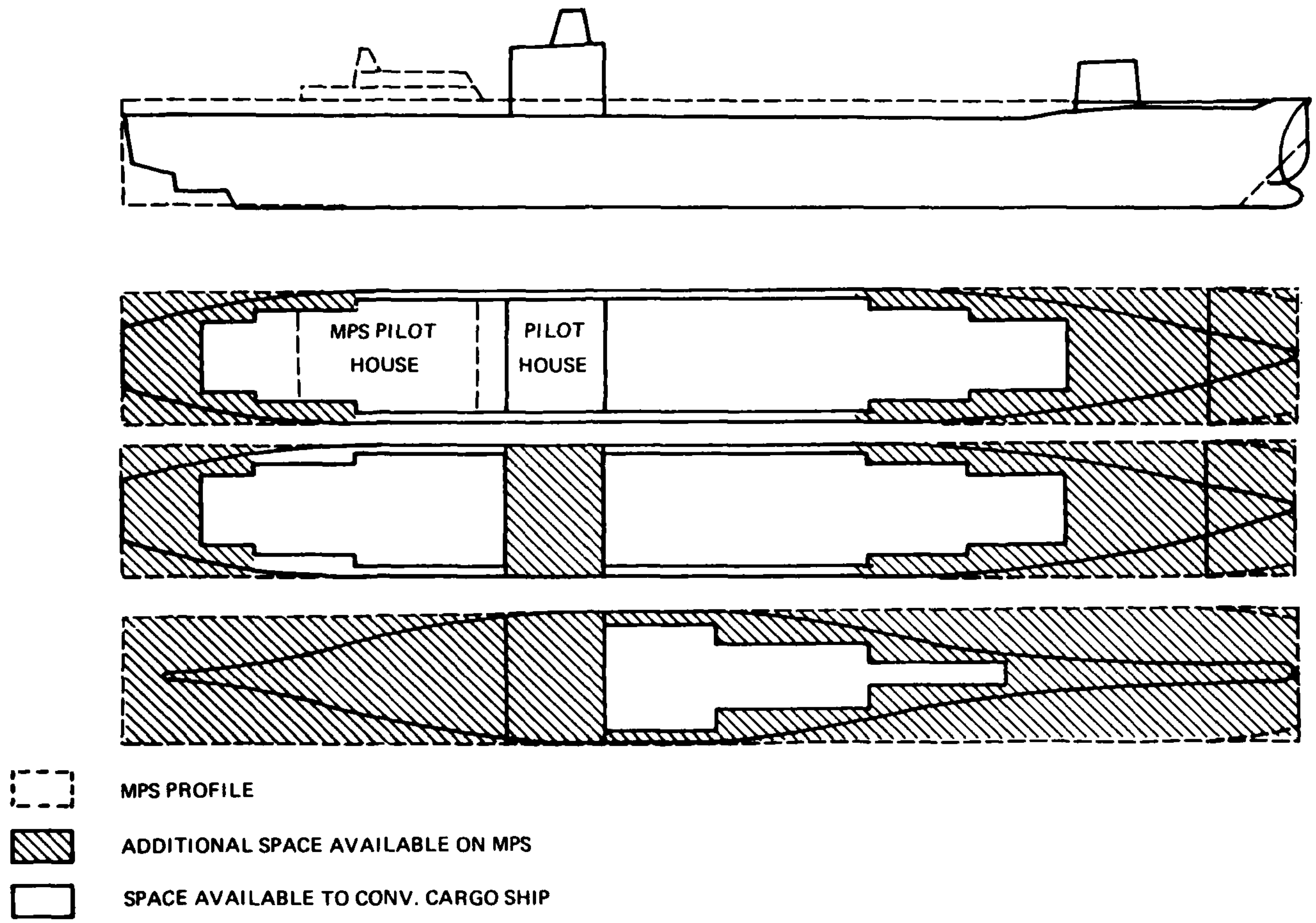


FIGURE A–1

CONTAINER CARGO

SHIP	FLD (LT)	PAYLOAD (LT)	LOAD[5] EFFICIENCY	TRANSPORT[6] EFFICIENCY	AVG. SPEED OUT (KTS)	LOAD TIME (D)	DAYS OUT	UNLOAD TIME (D)	AVG. SPEED IN (KTS)	DAYS IN
MPS	15,000	6,200[1]	.56	81.9	35	0.18	4.64	0.18	68	2.39
PD-214 (MA-134)	28,870	10,186[2]	.35	52.2	20	0.23	8.13	0.23	20	8.13
T-AKX (Jumbo PD-214)	37,830	12,733[3]	.35	65.3	20	0.29	8.13	0.29	20	8.13
SL-7	51,715	15,000[4]	.29	126.9	33	0.50	4.92	0.50	33	4.92

NOTES:

1 - 563 - 20 ft or 413 - 40 ft containers

2 - 926 - 20 ft or 679 - 40 ft containers

3 - 1157 - 20 ft or 849 - 40 ft containers

4 - 1000 - 40 ft containers. Alternate cargo 2000 - 20 ft containers

5 - Load Efficiency = Payload/FLD

6 - Transport Efficiency = (Cargo weight x Speed)/nm travelled, LT-Kts/nm

TABLE A-ii

RO/RO CARGO

SHIP	FLD (LT)	PAYLOAD (LT)	LOAD[5] EFFICIENCY	TRANSPORT[6] EFFICIENCY	AVG. SPEED OUT (KTS)	LOAD TIME (D)	DAYS OUT	UNLOAD TIME (D)	AVG. SPEED IN (KTS)	DAYS IN
MPS	11,400	3,400[1]	.30	51.9	51	0.34	3.19	0.34	68	2.39
PD-214 (MA-134)	28,870	6,158	.21	31.6	20	1.14	8.13	1.14	20	8.13
T-AKX (Jumbo PD-214)	37,830	7,698	.21	39.5	20	1.43	8.13	1.43	20	8.13
MPS	15,000[2]	6,562	.58	85.8	34	0.44	4.78	0.45	68	2.39
PD-214 (MA-134)	28,870	1,186[3]	.04	10.4	20	0.56	8.13	0.56	20	8.13
PD-214 (MA-134)	28,870	3,480[4]	.12	17.9	20	0.48	8.13	0.48	20	8.13

NOTES:

1 - Includes 359 LT of portable deck.

2 - Ship Gross Weight approximately 15,00 LT.

3 - 1/5 Airborne.

4 - 1/9 Armor.

5 - Load Efficiency = Payload/FLD

6 - Transport Efficiency = (Cargo Weight x Speed)/nm travelled, LT-Kts/nm

TABLE A-iii

A.3 SPEED

Additional data have been included in Tables A-ii and A-iii to account for speed, transit time, and load/unload times. These data have been plotted in Figures A-2 and A-3, for container and for RO/RO cargo respectively, for a 30 day mission and 3,900 nm transit. Figure A-2 indicates the advantage of speed. For containerized cargo, the SL-7 is superior; again because it was designed for that purpose. Its speed is comparable to that of the MPS but it carries over twice the payload. Figure A-3 shows the RO/RO cargo delivery capacities of the MPS, the PD-214, and the T-AKX. The latter carrying airborne and armored cargoes, as with the MPS. Also depicted is the military cargo that is defined in the PD-214 report (PD-214 Multi-Purpose Mobilization Ship, MARAD, November 1978). As shown in Figure A-3, the MPS will make four trips in the time the PD-214, or the T-AKX can make two.

CONTAINER CARGO
3,900 NM TRANSIT

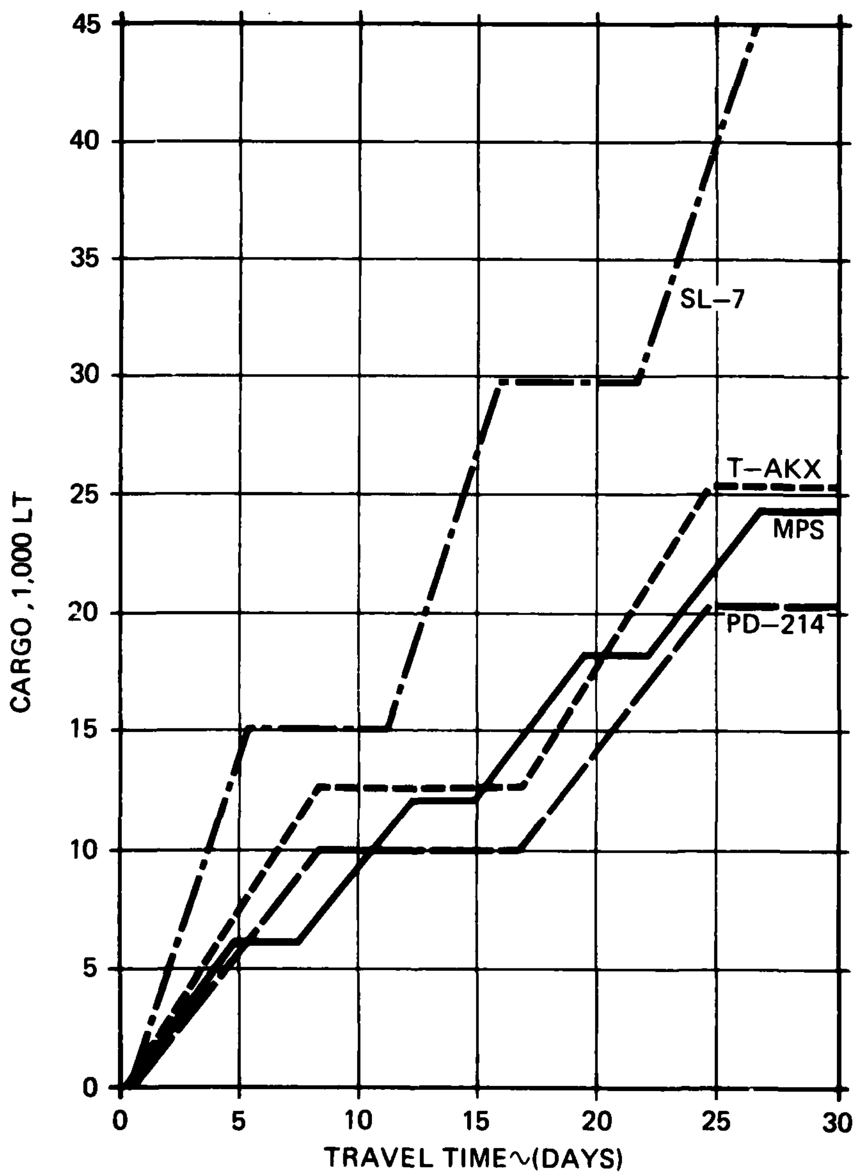


FIGURE A–2

RO/RO CARGO
3,900 NM TRANSIT

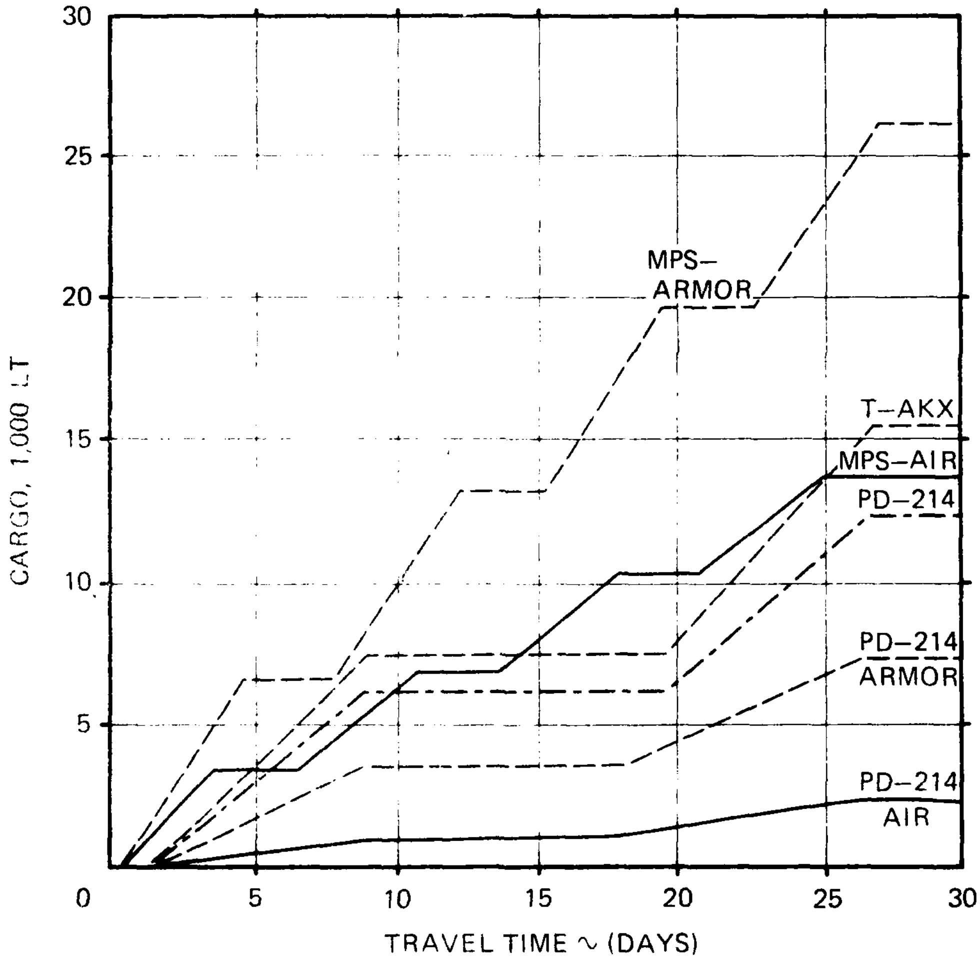


FIGURE A–3

APPENDIX B
CARGO LOADING/OFF-LOADING SYSTEM PRELIMINARY ANALYSIS

B.1 ASSUMPTIONS

- o Ship moored at pier (or in position) for load/off-load.
- o Adequate pier space and staging area to facilitate all types of off-loading.
- o Sufficient water for ballasting to maximum depth.
- o Sufficient skilled drivers and helicopter towing equipment to preclude delays if RO/RO utilized.
- o Sufficient personnel to secure/unsecure helicopters, direct all traffic and manually place non-self propelled vehicles if necessary, i.e., internal cargo handling system does not limit load/off-load evolutions.
- o No accidents or mechanical difficulties during load/off-load.
- o Shipboard cargo is defined as for preliminary time line calculations one-half an airborne division.

B.2 RO/RO (Ramps)

If the following additional assumptions are made:

- o upper deck internal handling and stowage systems allow unlimited flow of a single traffic line,
- o the optimum pier conditions allow stern/side load/off-load,
- o operational procedures allow simultaneous loading of aircraft and vehicles, and
- o the length of the access ramp is 30 ft;

then the maximum loading time is the greater of the summation of the off-load times for each traffic line. This can be represented by

$$\sum_{\substack{i=1,m \\ j=1,n}} t_{ij}$$

where "t" represents the time increment, "i" represents the vehicle type, and "j" represents a particular vehicle.

If the helicopters travel at one-half mph (44 ft/min) and maintain a 50-foot clearance at the top and the bottom of the ramp at all times, and only one helicopter on the ramp, then the load/off-load equals:

$$\sum_{j=1,\ \frac{48+93+74}{2}} t_{helo} = \sum_{j=1,\ 107.5} t_{helo}$$

$$\sum_{j=1,107.5} \frac{\text{distance}}{\text{speed}} = \sum_{j=1,107.5} \frac{50+30+50}{44} = \frac{130}{44}(107.5) = 318 \text{ min (5.3 hours)}$$

NOTE: This requires a sufficient number of properly designed tow bars and drivers to make transit to staging area, return transit to ship, access via another ramp, connect to helicopter and transit to off-load position without delaying off-load and vice versa for loading operations.

If wheeled vehicles travel at 3 mph (264 ft/min) and maintain one vehicle's length clearance, then vehicle load/off-load time equals (ignoring time of first vehicle down the ramp):

$$\sum_{j=1,22} t_{5\text{ ton}} + \sum_{j=1,135} t_{2\text{-}1/2\text{ ton}} + \sum_{j=1,347} t_{1\text{-}1/4\text{ ton}} + \sum_{j=1,400} t_{1/4\text{ ton}} + \sum_{j=1,1.5} t_{cc}$$

$$= \frac{1}{264}(22(26.6X2) + 135(23.2X2) + 347(19.3X2) + 400(11X2) + 1.5(16X2))$$

$$= \frac{1}{264}(1,170 + 6,264 + 13,394 + 8,800 + 48) = \frac{29,676}{264} = 112 \text{ min (1.9 hours)}$$

If the vehicles maintain a clearance of 50 ft at the top or bottom of the ramp at all times and only one vehicle is allowed on the ramp at a time, then the vehicle load/off-load time becomes:

$$\frac{80}{264}(22 + 135 + 347 + 400 + 1.5) = 274 \text{ min (4.6 hours).}$$

8.3 RO/RO (Deck Edge Elevators)

Assuming deck edge elevators can be synchronized to the level of the pier, then the off-load times could be similar to the RO/RO with ramps. However, an elevator can normally only deliver one helicopter at a time. Assuming that optimistically it takes 10 minutes to load/unload the elevator and to position it on the pier, off-load time would be time to get to off-load position plus the 30 ft ramp transit time: No. of helicopters $(t_{ramp} + t_{position}) = 107.5\ (\frac{30}{44} + 10) = 1,148$ min (19.1 hours).

Use of two elevators for helicopters could reduce the time to 9.5 hours, but at least one additional elevator or RO/RO ramp would be required to off-load vehicles. Consequently, even if six elevators were installed

(three on each side; two for helicopters and one for vehicles), the off-load time would be a minimum of 9.5 hours.

B.4 LO/LO

Assuming sufficient deck edge platforms or elevators are available to support the maximum number of cranes and that cranes and ships are readily available, then the off-load would only be limited by number of cranes that could safely operate in approximately 600 ft (the absolute maximum would be one crane every 100 ft if the main deck is all usable for load/off-load operations). Load/off-load time for only helicopters using one crane is estimated as follow:

Attack helo	24	@ 3/hr	8 hrs
Utility helo	46.5	@ 3/hr	15.5 hrs
Observation helo	37	@ 4/hr	9.3 hrs
	107.5		32.8 hrs

Assuming an average of 6 vehicles per hour could be loaded/off-loaded by a single crane, then the time required would equal:

$$1/6\ (22 + 135 + 347 + 400 + 1.5) = \frac{905.5}{6} = 150.9 \text{ hrs; thus, } 32.8 + 150.9$$

= 183.7 hours of crane operations are required and if six cranes were utilized, load/off-load operations would require 30.6 hours.

B.5 FO/FO

This load/off-load operation was considered, but with high transit ship speeds fly-off preparation would have to be done in port or inside the ship and then the helicopter moved to a designated fly away location. Both concepts have too high a time penalty, and the latter concept would decrease cargo stowage area. Consequently, the FO/FO is not really a viable alternative.

B.6 HELICOPTER TOWING LIMITATIONS

B.6.1 Ramp Design Criteria

Utilizing an assumed ground clearance of six inches and scaled dimensions from sketches of the attack, utility and observation helicopters in United States Army Aviation Planning Manual FM 101-20, the limiting knuckle angle calculated was 6.7^{o}, 6.3^{o} and 7.0^{o}, respectively. Consequently, maximum helicopter ramp angle was set at 5^{o}, with 4^{o} being the preferred maximum angle.

The length of the access ramps was based on the following data with the ship off cushion:

SHIP CONDITIONS	UNBALLASTED Displacement (LT)	Draft (FT)	MAXIMUM BALLAST Displacement (LT)	Draft (FT)
Initial Displacement	10,000	20.5	18,000	28.2
Less Fuel	8,507	18.8	16,507	26.9
Less Payload	6,700	16.6	14,700	25.2
Less Fuel and Payload	5,207	14.6	13,207	22.8

For the worst case, a pier height of 8 ft above the water at high tide is assumed. Consequently, in the no fuel, no payload situation, the ship must be ballasted from 14.6 ft to 22.8 ft to decrease the pier to egress deck (33 ft level) differential to 2.2 ft, resulting in ramp lengths of 25.2 ft and 31.5 ft and 5° and 4° ramp angles, respectively. If tides are extremely high or pier heights are low, the helicopters can be off-loaded first, the ship refueled or a tide change awaited. Low tides should not be a problem since the ship can be deballasted (8.2 ft draft reduction) and/or the lift system utilized (approximately a 12 ft draft reduction), providing a total compensation of over 20 ft.

B.6.2 FIFTH DECK CLEARANCE

Utilizing the utility helicopter characteristics from FM 101-20 (United States Army Aviation Planning Manual) and scaling off the pivot point distance from the tail, the deck clearance was obtained as follows:

Deck clearance = tail height + tail elevation (due to 5° incline) + ground clearance of the helicopter + clearance between helicopter and overhead
= 10.2' + 2.3' + 0.5' + 1.0' = 14.0 ft.

However, prior to reducing 15' deck clearance initially established, the following three assumptions should be physically verified:

1) Helicopter ground clearance
2) Minimum acceptable operational height clearance

B.7 SAMPLE CALCULATIONS OF TIME LINE ANALYSES

B.7.1 UNIT TRANSIT AND ACCELERATION/DECELERATION TIMES

1. Transit Time: $t = \frac{d}{v}$ distance, d and speed, v

Helicopter: $t = \frac{40 \text{ ft}}{1/2 \text{ mph}} = \frac{40 \text{ ft}}{44 \text{ ft/min}} = 0.9 \text{ min}$

Other Vehicles: $t = \frac{20 \text{ ft}}{1\ 1/2 \text{ mph}} = \frac{20 \text{ ft}}{132 \text{ ft/min}} = 0.15 \text{ min}$

2. Acceleration/Deceleration Times: Assuming constant acceleration and 20 ft is needed for all cargo to accelerate or decelerate

from transit speed from a stop or to a stop, then: a = acceleration = v/t

$$d = v_o t - 1/2\ at^2 = v_o t - 1/2 \frac{v}{t} (t^2) = t\ (v_o - 1/2\ v)$$

$$t = \frac{d}{v_o - 1/2\ v} = \frac{20}{v_o - 1/2\ v}$$

Helicopter: $t = \frac{20}{44\ (1/2)} = 0.9$ min; Other vehicles: $t = \frac{20}{132(1/2)} = 0.3$ min

B.7.2 AIRBORNE DIVISION STERN LOADING TIME

Assume all vehicles on the fifth deck are helicopters for time calculations, 0.5 minute is required to disconnect tow bar and to clear the area for the next helicopter to park, and a 5 minute delay is incurred for the first manually parked helicopter and 3 minutes for each additional manually parked helicopter. "Manually parked" means pushed by a crew of approximately five people or winched in place by a placement/ tiedown crew of approximately three people utilizing a portable electrically powered come-along and hydraulic dolly.

1. Row 1 Sequence:

   - Load fifth deck (tank deck) center space "C" to after ramps.
   - Lower after hinged ramp (10 min, est.)
   - Load decks above fifth deck.
   - Load aft section of fifth deck center space.

2. Row 2 Sequence:

   - Load fifth deck helicopters in spaces A, B, D, & E.
   - Assume sequence of A, E, D, & E for calculations.

3. Row 1 Stern Loading Time Calculation:

$$TL_{TT"C"FWD} = T_{t_1} + \sum T_{m_i} = \frac{634}{44} + 14\ (0.9_{transit} + 0.9_{stop} + 0.5) + 4(0.15_{transit} + 0.3_{stop}) = 14.4 + 32.2 + 1.8 = 48.4 \text{ min}$$

$$TL_{lower\ ramp} = 10 \text{ min (est.)}$$

$$TL_{above\ decks} = T_{t_1} + \sum T_{m_i} = \frac{889}{132} + (224 + 385 + 275)\ 0.45 = 6.7 + 397.8 = 404.5 \text{ min.}$$

$$TL_{TT"C"\ aft} = T_{t_1} + \sum T_{m_i} = 5 + 7\ (3)^* = 26 \text{ min}$$

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* These helicopters require manual placement and this estimate is based on 5 minutes for the first helicopter and an average of 3 minutes per helicopter for the last 7.

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$TL\ Row\ 1 = TL_{TT"C"FWD} + TL_{lower\ ramp} + TL_{above\ decks} + TL_{TT"C"aft} =$

$48.4 + 10.0 + 404.5 + 26.0 = 499$ min or 8.3 hr

4. <u>Row 2 Stern Loading Time Calculation</u>:

$TL_{TT"A"} = {}^{T}t_1 + {}^{T}m_i = \frac{634}{44} + 19(2.3) + 5 + 3 + 7(0.45) =$

$14.4 + 43.7 + 5 + 3 + 3.2 = 69.3$ min

$TL_{TT"B"} = {}^{T}t_1 + {}^{T}m_i = \frac{634}{44} + 22(2.3) + 0.45 = 14.4 + 50.6 + 0.45 =$

65.5 min

$TL_{TT"D"} = TL_{TT"B"} = 65.5$ min

$TL_{TT"E"} = TL_{TT"A"} = 69.3$ min

$TL_{Row\ 2} = TL_{TT"A"} + TL_{TT"B"} + TL_{TT"D"} + TL_{TT"E"} = 69.3 + 65.5 + 65.5 +$

$69.3 = 269.6$ min or 4.5 hr

5. <u>Stern Loading Time</u>:

$TL_{Stern} = TL_{Rig\ stern\ ramps} + TL_{Row\ 1} + TL_{Stow\ ramps} = 30$ min (est.) +

$499 + 20 = 549$ min or 9.2 hr

APPENDIX C
OPERATING PROFILE RATIONALE FOR MPS

MPS nominal range is 3,900 nautical miles. Nominal speed varies according to the payload and fuel weights. During the return trip, the nominal speed is 68 knots with no cargo.

The scenario assumes that refueling would not be done during loading and off-loading cargo because of risk to cargo and ship in the event of accident or act of war. Fuel piers are usually located at sites separate from embarkation piers. Ship fuel at the port of debarkation was assumed to be available during the period of mobilization.

The following estimates were used for the duration period of inport fueling:

Gallons (90% of 500,000)	:	450,000
Transfer Capacity (gal/hr)	:	225,000
Duration of pumping (hrs)	:	2

Another three hours are estimated for berth shifts, hook up and disconnect of fuel lines and tie-up at the dock for loading cargo. Total fueling and dock tie up time is estimated to be about five hours at the port of debarkation. At the port of embarkation, dock tie up time is estimated to be two hours and another three hours for refueling.

Loading and off-loading times reflect loading and off-loading through the stern ports and side ports as discussed in Section 6.1.5 of this report.

Refueling at sea was assumed to be performed when the ship was at 50% capacity or less. The pumping capacity would be 125,000 gallons per hour or greater. The pumping duration was estimated at about two hours with an additional hour allocated for rendezvous, approach, connect and disconnect. Nominal refueling at sea was estimated at about three hours.

Performance of corrective and preventive maintenance of mission critical and essential equipments after the end of each round trip will be made during loading. This should minimize maintenance efforts during the underway operational periods.

APPENDIX D

WIND AND SEA SCALE FOR FULLY ARISEN SEA

Sea State (1)	Sea General: Description (2)	Wind (1): (Beaufort) Windforce	Wind: Description	Wind: Range (Knots)	Wind: Wind Velocity (Knots) (a)	Sea (1): Wave Height Feet: Average	Wave Height Feet: Significant	Wave Height Feet: Average 1/10 Highest	Significant Range of Periods (Seconds)	T_{max} (Period of Maximum Energy of Spectra)	$\bar{T}$ Average Period	$\bar{L}$ (Average Wave Length)	Minimum Fetch (Nautical Miles)	Minimum Duration (Hours)
0	SEA LIKE A MIRROR	0	CALM	LESS THAN 1	0	0	0	0	—	—	—	—	—	—
	RIPPLES WITH THE APPEARANCE OF SCALES ARE FORMED BUT WITHOUT FOAM CRESTS.	1	LIGHT AIRS	1 - 3	2	0.05	0.08	0.10	UP TO 1.2 SEC	0.7	0.5	10 IN	5	18 MIN
1	SMALL WAVELETS, STILL SHORT BUT MORE PRONOUNCED. CRESTS HAVE A GLASSY APPEARANCE, BUT DO NOT BREAK.	2	LIGHT BREEZE	4 - 6	5	0.18	0.29	0.37	0.4–2.8	2.0	1.4	6.7 FT	8	39 MIN
	LARGE WAVELETS. CRESTS BEGIN TO BREAK. FOAM OF GLASSY APPEARANCE. PERHAPS SCATTERED WHITE HORSES.	3	GENTLE BREEZE	7–10	8.5	0.6	1.0	1.2	0.8–5.0	3.4	2.4	20	9.8	1.7 HRS
					10	0.88	1.4	1.8	1.0–6.0	4	2.9	27		2.4
2	SMALL WAVES, BECOMING LARGER; FAIRLY FREQUENT WHITE HORSES.	4	MODERATE BREEZE	11–16	12	1.4	2.2	2.8	1.0–7.0	4.8	3.4	40	18	3.8
					13.5	1.8	2.9	3.7	1.4–7.6	5.4	3.9	52	24	4.8
					14	2.0	3.3	4.2	1.5–7.8	5.6	4.0	59	28	5.2
3					16	2.9	4.6	5.8	2.0–8.8	6.5	4.6	71	40	6.6
4	MODERATE WAVES, TAKING A MORE PRONOUNCED LONG FORM; MANY WHITE HORSES ARE FORMED. (CHANCE OF SOME SPRAY).	5	FRESH BREEZE	17–21	18	3.8	6.1	7.8	2.5–10.0	7.2	5.1	90	55	8.3
					19	4.3	6.9	8.7	2.8–10.6	7.7	5.4	99	65	9.2
					20	5.0	8.0	10	3.0–11.1	8.1	5.7	111	75	10
5	LARGE WAVES BEGIN TO FORM; THE WHITE FOAM CRESTS ARE MORE EXTENSIVE EVERYWHERE. (PROBABLY SOME SPRAY).	6	STRONG BREEZE	22–27	22	6.4	10	13	3.4–12.2	8.9	6.3	134	100	12
					24	7.9	12	16	3.7–13.5	9.7	6.8	160	130	14
					24.5	8.2	13	17	3.8–13.6	9.9	7.0	164	140	15
6					26	9.6	15	20	4.0–14.5	10.5	7.4	188	180	17
	SEA HEAPS UP AND WHITE FOAM FROM BREAKING WAVES BEGINS TO BE BLOWN IN STREAKS ALONG THE DIRECTION OF THE WIND. (SPINDRIFT BEGINS TO BE SEEN).	7	MODERATE GALE	28–33	28	11	18	23	4.5–15.5	11.3	7.9	212	230	20
					30	14	22	28	4.7–16.7	12.1	8.6	250	280	23
					30.5	14	23	29	4.8–17.0	12.4	8.7	258	290	24
					32	16	26	33	5.0–17.5	12.9	9.1	285	340	27
7	MODERATELY HIGH WAVES OF GREATER LENGTH; EDGES OF CRESTS BREAK INTO SPINDRIFT. THE FOAM IS BLOWN IN WELL MARKED STREAKS ALONG THE DIRECTION OF THE WIND. SPRAY AFFECTS VISIBILITY.	8	FRESH GALE	34–40	34	19	30	38	5.5–18.5	13.6	9.7	322	420	30
					36	21	35	44	5.8–19.7	14.5	10.3	363	500	34
					37	23	37	46.7	6–20.5	14.9	10.5	376	530	37
					38	25	40	50	6.2–20.8	15.4	10.7	392	600	38
					40	28	45	58	6.5–21.7	16.1	11.4	444	710	42
8	HIGH WAVES. DENSE STREAKS OF FOAM ALONG THE DIRECTION OF THE WIND. SEA BEGINS TO ROLL. VISIBILITY AFFECTED.	9	STRONG GALE	41–47	42	31	50	64	7–23	17.0	12.0	492	830	47
					44	36	58	73	7–24.2	17.7	12.5	534	960	52
					46	40	64	81	7–25	18.6	13.1	590	1110	57
	VERY HIGH WAVES WITH LONG OVERHANGING CRESTS. THE RESULTING FOAM IS IN GREAT PATCHES AND IS BLOWN IN DENSE WHITE STREAKS ALONG THE DIRECTION OF THE WIND. ON THE WHOLE THE SURFACE OF THE SEA TAKES A WHITE APPEARANCE. THE ROLLING OF THE SEA BECOMES HEAVY AND SHOCK LIKE. VISIBILITY IS AFFECTED.	10	WHOLE GALE *	48–55	48	44	71	90	7.5–26	19.4	13.8	650	1250	63
					50	49	78	99	7.5–27	20.2	14.3	700	1420	69
					51.5	52	83	106	8–28.2	20.8	14.7	736	1560	73
					52	54	87	110	8–28.5	21.0	14.8	750	1610	75
					54	59	95	121	8–29.5	21.8	15.4	810	1800	81
9	EXCEPTIONALLY HIGH WAVES (SMALL AND MEDIUM SIZED SHIPS MIGHT FOR A LONG TIME BE LOST TO VIEW BEHIND THE WAVES). THE SEA IS COMPLETELY COVERED WITH LONG WHITE PATCHES OF FOAM LYING ALONG THE DIRECTION OF THE WIND. EVERYWHERE THE EDGES OF THE WAVE CRESTS ARE BLOWN INTO FROTH. VISIBILITY AFFECTED.	11	STORM *	56–63	56	64	103	130	8.5–31	22.6	16.3	910	2100	88
					59.5	73	116	148	10–32	24	17.0	985	2500	101
	AIR FILLED WITH FOAM AND SPRAY. SEA COMPLETELY WHITE WITH DRIVING SPRAY. VISIBILITY VERY SERIOUSLY AFFECTED.	12	HURRICANE *	64–71	>64	(b) 80	(b) 128	(b) 164	10–(35)	(26)	(18)	~	~	~

NOTES

(a) A HEAVY BOX AROUND THIS VALUE MEANS THAT THE VALUES TABULATED ARE AT THE CENTER OF THE BEAUFORT RANGE.

(b) FOR SUCH HIGH WINDS THE SEAS ARE CONFUSED. THE WAVE CRESTS BLOW OFF AND THE WATER AND THE AIR MIX.

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(3) PRACTICAL METHODS FOR OBSERVING AND FORECASTING OCEAN WAVES, PIERSON, NEUMANN, JAMES, N.Y. UNIV. COLLEGE OF ENGIN. 1953.

* FOR HURRICANE WINDS (AND OFTEN WHOLE GALE AND STORM WINDS) REQUIRED DURATIONS AND FETCHES ARE RARELY ATTAINED. SEAS ARE THEREFORE NOT FULLY ARISEN.

Adapted from Material Originally Prepared by Wilbur Marks, David W. Taylor Naval Ship Research and Development Center, With Added Data by M. Shin.

For additional information or queries regarding this study, please contact Study Coordinator Michael Stoiko on (202)227-1295